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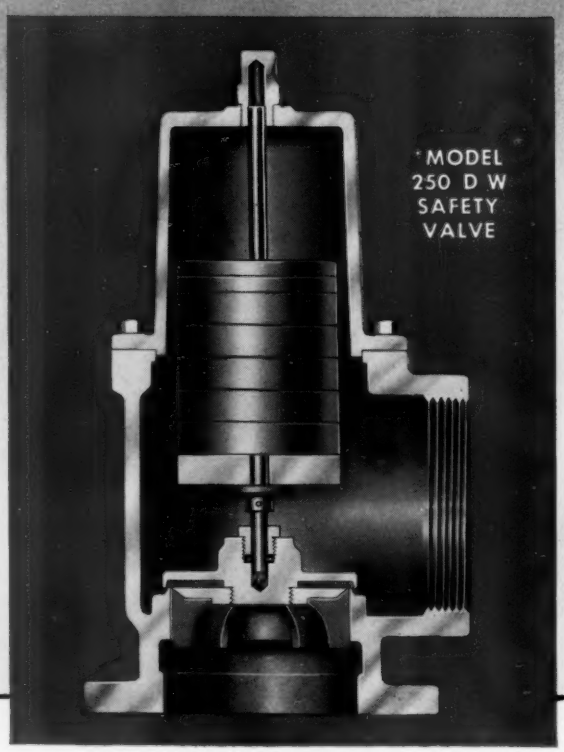

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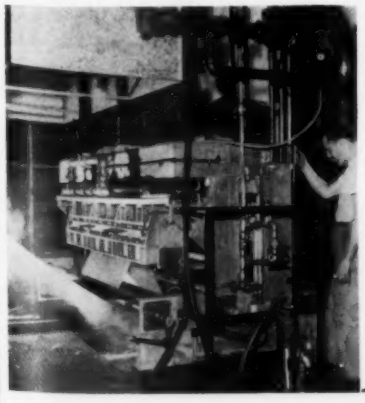

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AMERICAN Gas Journal
ESTABLISHED 1859

VOLUME 177 OCTOBER 15, 1952 NUMBER 5

This month...

In preparing the annual *American Gas Handbook* issue of AMERICAN GAS JOURNAL we are invariably impressed, not with the paucity of material that might reasonably be utilized, but rather with the wealth of new—or perhaps newly considered—data, articles, tables and kindred references that seem to clamor for inclusion.

The task of selecting from the mass of all industry literature those data related to gas that should be readily at hand for the daily use of the operating gas man is a formidable one. The further responsibility of refining the contents so that they can be encompassed within the limited space available in *American Gas Handbook* is still more exacting. The responsibility for that selection and refining rests again, with this edition, in the hands of Charles R. Bellamy, technical editor of AMERICAN GAS JOURNAL and editor of the *Handbook* issue.

The advancement of the gas industry rests on more than the mere improvement of its own technologies in the handling of the product offered for sale. In the last analysis, the ultimate aim and justification of all production is consumption. No progress in the science of production, transmission and distribution of gas can have significance unless it has, as its goal, an enhanced and more effective utilization of the fuel itself.

Much of the basic and applied research that makes possible this utilization progress is carried on continuously by the manufacturers of gas equipment.

For that reason another new listing, that of New Technical Literature issued by manufacturers of gas equipment, has been added here for the first time. In both basic and applied research the industry's supplying manufacturers are the vanguard of research and development.

It also seems appropriate to call again to the attention of *Handbook* users that the product information presented by advertising manufacturers is in many instances on a par with the editorial material.

As in the past, the *American Gas Handbook* issue of AMERICAN GAS JOURNAL is presented as a service to the gas industry, and distributed without additional charge to AMERICAN GAS JOURNAL subscribers.

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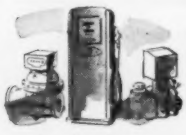

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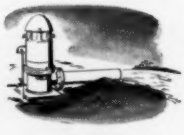

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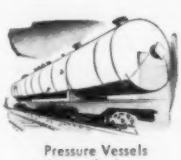

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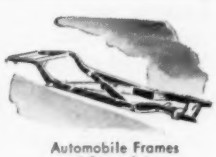

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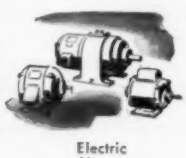

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Experience and Practices in Gas Odorizing in the Niagara Mohawk System

by T. C. Moran

System Operating Engineer—Gas
Niagara Mohawk Power Corporation

THE Niagara Mohawk system, in Upstate New York, began receiving natural gas in September 1932, for use in an 875 Btu mixture with manufactured gas. Odorization was not generally practiced until we changed to straight natural gas, in December 1947.

Some of the natural gas was sold as straight natural, without odorization, to interruptible industrial customers from new steel lines that were laid, in part, in city streets to reach those industrials. An old mile-long cast iron line was used to bring gas through city streets to heat our central office. This gas was odorized and represented our first odorization practice.

The dilute sulphide type of odorant was used at a rate of about thirteen pounds or two gallons per MMcf and proved satisfactory to the extent that we had no trouble or incidents during the period. It was dripped into the line at the regulator station servicing it.

The mixed gas was 70 per cent natural and 30 per cent coal gas. That percentage of manufactured gas added sufficient odor. For one year, from December 1946 to December 1947, we distributed a 950 Btu mixture which was only ten to fifteen per cent manufactured gas. This mixture still carried a distinctive odor and no odorant was added.

Straight natural gas was turned into the Syracuse-Oswego area of 78,000 customers in December 1947 and a city gate odorizer was started on the same date. The odorizer is of the mechanical type, using the gas meter and Archimedes pump mechanism. The odorant used was the dilute sulphide type. This type odorant was used for two years. During the period, monthly rates ran from 8.2 pounds per MMcf minimum to 13.0 pounds maximum, with 9.8 pounds per MMcf as a good yearly average. The record shows that no question of the intensity of the odor was ever raised in connection with any incident or claim.

Changed to concentrated odorant

For the sole purpose of reducing the bulk of material handled, this area went over to concentrated type of cyclic sulphide in January 1950. The quantity of the concentrate used in two parallel odorizers, treating a maximum of 85 MMcf per day and minimum of 12 MMcf is not sufficient to give good rate determination. So, for that reason and the tendency of the dilute to be somewhat more persistent, we changed to a 50-50 mixture of concentrate and dilute and today the Syracuse-Oswego area is operating on this special mixture. Rates on the concentrate average .58 pounds per MMcf and are currently averaging 1.15 pounds per MMcf on this special mixture.

This rate of odorant gives satisfactory intensity at the system ends, 50 miles away at Oswego and 47 miles away at Vernon. It may be effective at greater distances but these are the limits of our system supplied from the Therm City Station. There are 83,000 gas customers now receiving gas odorized with this material, all injected at the city gate station.

Late in 1951, our company introduced straight natural gas into two more major service areas, the Utica division and the Eastern division consisting of the metropolitan area at Albany-Schenectady-Troy.

The Utica division is served from one city gate station and the Eastern division from three. We use the same type odorizers at each as used at Syracuse. In these recently-changed areas, we are using the concentrated mercaptan type odorant, which does not indicate any dissatisfaction with the sulphide type. We are obtaining comparative results on these two widely used types of odorant material.

There are approximately 200,000 customers of Niagara Mohawk being served with mercaptan-odorized gas.

Odorant-injection rates

Rates of odorant-injection are as follows: minimum rate, monthly, 0.56 pounds per MMcf; maximum rate, monthly, 1.044 pounds; average rate, to date, 0.78 pounds.

The maximum distance from point-of-odorization to end-of-system is 45 miles, from South Schenectady to Hudson Falls. Odor intensity at the remote point is adequate.

Control of injection rate

The question of how much of any odorant to add is probably the most difficult to answer. From the beginning and to date, our method of control is still ultimately by the sense of smell. First, we record daily the amount of odorant and MMcf passed at the station and convert that to pounds per MMcf to determine that the apparatus is proportioning the material to the rate of gas flow. But that, of itself, does not tell us that we have the odor intensity that we wish at the end of our system. Rates recommended by the suppliers give us something to shoot at.

We believe that only by a *smell test at remote points of utilization* can we learn what results we are getting. Then we adjust the rate-of-feed at the odorizer to the pounds per MMcf which will yield the desired results at the test points. In each district these tests are made daily by our employees and reported to the superintendent's office. The intensity is graded as none, weak, adequate, excessive.

Diluter devices, to assist the tester in obtaining a more uniform calibration, are soon to be available. Basically, these devices mix measured proportions of odorized gas and unodorized gas or air into a face piece and indicate the relationship to the minimum or threshold odor intensity.

The room test is a semi-laboratory method and although we have made several such tests, we do not use it regularly for operating control, due to its cumbersome nature.

In 1947, there was nothing approaching agreement in the natural gas industry in regard to the necessity of odorizing natural gas. Lately, there appears to be a clarification in regard to distribution of odorized gas. The 1951 report of the National Association of Railroad and Utility Commissioners, in their proposed uniform rules, says,

"Gas Odor—All gas supplied to customers shall possess a distinctive odor to act as an indication of its presence, except when service is rendered directly from transmission lines or when specifically exempted by Commission.

"Any gas which does not naturally possess such an odor shall have added to it an odorant to meet the above re-

(Continued on page 190)

Properties of Natural Gas Odorants

by Charles R. Cable*
P. A. Turcotte†
Frank H. Dotterweich‡

THE program undertaken to study the properties of natural gas odorants and how they may be more effectively used as a warning agent in the natural gas industry has been carried out in three phases at the Texas College of Arts and Industries, Kingsville, Texas.

The first phase of the work was an evaluation of the odor characteristics of commercial odorants, including a study of their chemical and physical properties. The second and third phases, laboratory and pilot plant respectively, were directed toward the sorptive properties of natural gas odorants when passing through various soils.

By means of room tests (1) some twenty-six odorants were tested. In more than 100 tests, reactions from more than 200 people were obtained. From this work with the two types of odorants, concentrated and dilute, effective odorization seems to require one-half pound of concentrated odorant and five pounds of dilute odorant per million cubic feet of gas, under average operating conditions, when the more common odorants were being used.

The average results of the tests conducted on concentrated and dilute odorants to date are indicated in figure 1.

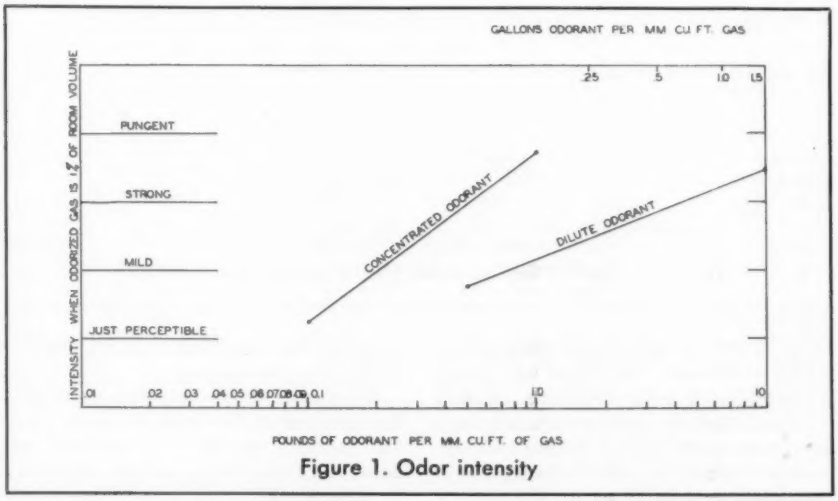

Figure 1. Odor intensity

A study of the physical and chemical properties revealed that the commercial odorants, stored as liquids to be vaporized and carried throughout a system, must have boiling points falling within certain limits. This property suggests that if odorants are removed while passing through soil and other media their sorption characteristics should not show any appreciable difference. However, soils having different surface or colloidal content should have varying sorptive capacities.

The second phase of the study(2) was carried out in the laboratory to observe certain general fundamentals relating to the sorptive properties of various soils for odorized gas.

Various soils were placed in a vertical three inch pipe, 36 inches long, and tests were conducted to observe the sorptive capacity of the soils under varying rates of flow for natural gas containing one-half pound of concentrated odorant per million cubic feet of gas. To study the relation of sorptive capacity to surface content of the soil, the surface content of the soils was gauged by means of dye adsorption (3). The results of these tests on four samples, weathered limestone, cinders, caliche and sand, are noted in table 1 and shown graphically in figure 2. These data are shown graphically in figure 3, using a semi-log plot, indicating the sorptive properties of rates of flow for two, four and six cubic feet of gas per hour when plotted versus surface content of the soil as determined by dye adsorption. The cinders sample did not exhibit fundamental adsorptive properties as did the other samples.

It appeared, from the tests, that adsorption was playing a major role in removing the odorant from natural gas. Large scale pilot plant tests, more representative of actual conditions experienced in field operations, were devised and conducted.

The third and final phase of this work was a pilot plant study of the sorptive properties of various soils (4). In this study, a vertical ten inch pipe, twelve feet long, was filled with the sample to be tested. The samples were the

TABLE 1

ODORANT GAS SORPTION DATA

SAMPLE	Weight (lbs.)	Gas (cu.ft.)	Time (hrs.)	Gas, cu.ft./ sample lb.	Gas, cu.ft./hr.	Dye adsorbed per sample gr. (milligrams)
Weathered limestone	14.2	60.4	25.0	4.32	2.27	246
	14.0	58.9	13.0	4.21	4.53	246
	14.1	56.2	6.0	3.98	9.37	246
Cinders	14.1	78.1	17.0	5.53	4.58	184
	13.8	73.7	12.5	5.34	5.9	184
	13.5	68.3	8.75	5.06	7.8	184
	13.4	62.5	6.25	4.67	10.0	184
Caliche	16.9	29.6	15.0	1.75	1.97	105
	16.8	21.9	5.5	1.31	3.99	105
	16.5	12.2	2.0	.74	6.1	105
Sand	19.0	21.6	8.33	1.14	2.59	24
	21.0	19.1	5.25	.91	3.65	24
	21.2	16.1	3.0	.76	5.37	24

* Freeport Sulfur Company, Freeport, Texas.
† The Ohio Oil Company, Henderson, Texas.
‡ Texas College of Arts and Industries, Kingsville, Texas.

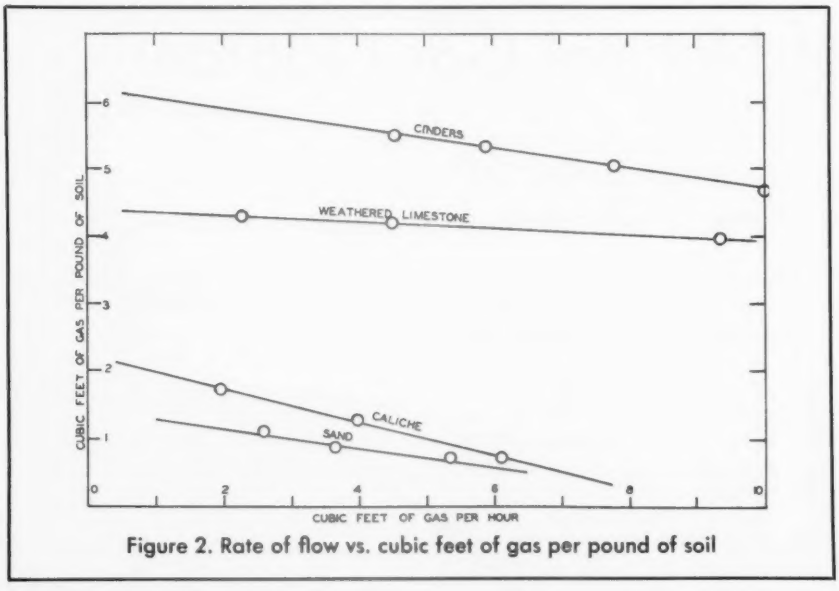

Figure 2. Rate of flow vs. cubic feet of gas per pound of soil

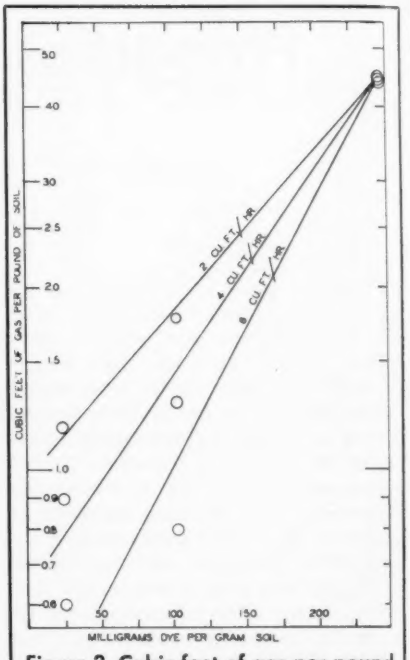

Figure 3. Cubic feet of gas per pound of soil vs. mgms of dye per gram of soil

same as used in the second phase of the work. In addition, black soil was tested. The results of these tests are reported in table 2 and presented graphically on a straight plot in figure 4. These data appear to confirm the laboratory studies in that adsorption is primarily the method by which the odorant is removed, with the exception of the cinder sample.

The sorptive properties noted may possibly be explained as follows: Most commercial odorants are sulfur compounds of one kind or the other with odor strengths in ascending order, that is: disulphides, thioethers, cyclic compounds and mercaptans. The mercaptans in various combinations are more widely used, and their odor strength in ascending order is methyl, ethyl, butyl, propyl and isoamyl mercaptan. Thus, for a given odor concentration, smaller amounts of the heavier mercaptans would be required.

It should be noted that the ability of a soil to adsorb increases with the molecular weight of the compound.

It has been reported (5) that a gas odorized with a mercaptan odorant, in leaking from a pipe line and passing through soil, may have its odor intensity reduced by these three possible actions:

(a) physical adsorption of the mercaptan by the soil; (b) chemical absorption of the mercaptan by the soil constituents; (c) oxidation of the mercaptan to a disulfide in the presence of soil constituents.

In this report, J. S. Powell noted that mercaptans are oxidized in the presence of iron oxide to disulphides. Thus, in the case of the cinder sample, it may be concluded that since the gas was odorized with an odorant chiefly composed of mercaptans that these compounds were oxidized to the less odoriferous and more adsorbable disulphide, thereby accounting for the different properties exhibited by this sample.

By similar reasoning, it appears that the removal of the odorant while passing through weathered limestone, caliche, sand and black soil was primarily by adsorption.

These sorptive properties of soils for commercial odorants create a hazard when odorized natural gas leaks from the system and passes through soil before entering an enclosed area. The amount of deordorized gas which will enter the room before it is detectible will depend upon the type of odorized gas and the amount and type of soil it passes through. Figure 5 has been constructed for natural gas containing one-half pound of a concentrated odorant passing through various soils and entering an air-tight room in which the lower explosive limit is assumed to be five per cent by volume gas.

The formula for such a system was developed as follows: The equation for the line plotted in figure 4 is $y = 5w_d + 0.69$, where "y" equals volume in cubic feet per pound of soil, and "w" equals weight of malachite green adsorbed in grams per gram of soil.

By multiplying both sides by the weight of the soil, a formula is obtained for the volume of gas in cubic feet that must pass through "W" pounds of soil before it could be detected: $Q = (5w_d + 0.69)W$.

Room tests using natural gas with .5 pound of odorant per million cubic feet indicated that an odorized gas concentration of .047 per cent must be obtained in a room of volume "V" before it can be detected.

Adding this factor to the above equation obtains this formula for the volume of gas escaping through soil into a room before an odor can be detected: $Q = (5w_d + 0.69)W + 0.00047V$.

These formulae show that the odor lost by the natural gas varies directly with the amount and colloid content of the soil incurred while escaping. Assuming the lower explosive limit of natural gas to be five per cent, a relationship between the volume of the

(Continued on page 191)

TABLE 2

ADSORPTION DATA

For gas flow rates of from five to ten cubic feet per hour

SAMPLE	Dye adsorbed per sample gr. (grams)	Gas (cu.ft.)	Soil (lbs.)	Gas, cu.ft./soil lb.
Weathered limestone	0.246	900	471	1.91
Cinders	0.184	1300	400	3.25
Caliche	0.105	510	453	1.13
Sand	0.024	510	580	0.88
Black soil	0.519	—	—	3.40

Design and Operation of Baltimore Oil Foggers

by O. W. Lusby
Consolidated Gas Electric Light and Power Company of Baltimore

THE new type of hot oil fogger developed for operations at Baltimore embodies the principles of heating the sweep gas rather than supplying direct heat to the oil; continuously contacting the hot gas with fresh oil, and continuously removing the residue of unvaporized oil from contact with the gas stream. The fogging rate is positively controlled through the rate at which oil is added to the gas by a controlled-volume pump.

Two years of trouble-free operation have demonstrated the advantages of this type of fogging equipment. The fog produced has excellent stability, and has been found widely distributed throughout the system.

A means of clearly establishing the presence of oil fog in the gas has been developed.

Approximately six weeks prior to the introduction of natural gas, we started oil fogging operations in an effort to assure an oil wet distribution system before conversion. When natural gas was temporarily introduced into the system at other points to facilitate conversion, small oil foggers were placed in operation at these locations to oil wet any dust present so as to prevent its movement.

In considering the conditioning of natural gas prior to conversion, it was decided to try to condition the mains so that they would continue to function the same with natural gas as when manufactured gas was distributed. This involved both humidifying and adding oil to the natural gas. In this way it was hoped that the leakage and dust troubles encountered by others after conversion to natural gas would at least be minimized.

An additional reason for the application of oil fog was to coat with oil the rust in the mains and thus reduce to a large extent the removal of the mercaptan-type odorant we were using. This removal is accelerated by the catalytic action of the iron oxide.

An investigation of the literature and a study of our previous experience indicated clearly that the hot oil fogger, which utilizes the principle of obtaining oil fog by suddenly cooling a hot gas stream carrying oil vapor, produces a fog of maximum stability and carrying power.

Seven fogging considerations

Our experience with oil fogging, covering a number of years, had brought to light many features which it appeared should be incorporated in the design of a hot oil fogger to obtain continuous trouble-free operation, adequate control of fogging rates and maximum fog stability. These factors are briefly as follows:

1. No heat should be applied directly to the oil. The necessary heat should be supplied to the "sweep" gas before contracting the oil to be vaporized. In this way the possibility of the carbonization of the oil on heat transfer surfaces with consequent adverse effect on fogging rates is avoided.
2. The heated gas should preferably be made to flow counter-current to the oil in order to obtain maximum vaporization of the oil for a given sweep gas flow and temperature.
3. In order to adequately control the fogging rate, the fresh oil should be added to the heated gas stream in a positively controlled manner which eliminates any possibility of flooding and over-fogging.
4. In order to maintain constant fogging rates, the spent oil residue should be removed continuously from the vaporization tower of the fogging equipment and not permitted to return to or mix with the fresh fogging oil.
5. The hot gas carrying the oil vapor should be introduced directly into the main gas stream. In this way the gas is cooled rapidly and a high concentration of fog particles is avoided and coalescence thereby reduced.
6. Open flames should be eliminated to reduce fire and explosion hazards. This permits the installation of these foggers at the most advantageous locations.
7. As a further safety measure, the heating of large volumes of oil in the fogger should be avoided. The design should also permit the storage of fogging oil at any convenient, safe location.

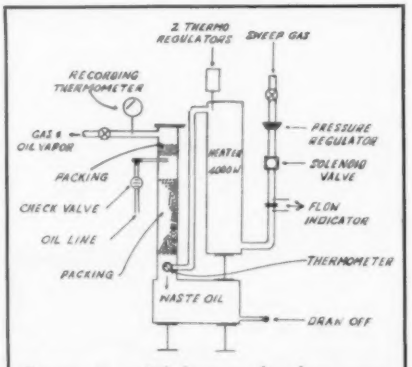

Figure 1. Oil fogger for low pressure stations, designed to fog 7.5 gals. of oil per day. Sweep gas 800-1,000 cu. ft. per hr.

We were unable to find on the market a hot oil fogger meeting these requirements. Foggers were therefore developed, incorporating the indicated features. Extensive experience has been secured by our operating department with all three types with entirely satisfactory results.

The first drawing shows a small fogger designed for an outlying station where oil requirements are limited to a few gallons per day.

This fogger was designed to operate at a station where the gas pressure is reduced. The sweep gas is passed through the fogger from the high to the low pressure main and the gas flow is controlled by adjusting the pressure regulator shown on the right of the drawing.

A solenoid valve follows the pressure regulator. With this arrangement the operation of the fogger can be made entirely automatic by connecting a timing device.

Following the solenoid is an orifice which may be used with either an indicating or recording flowmeter to measure the flow of sweep gas.

The cold sweep gas enters the bottom of the electric heater which has a capacity of four to five thousand watts. This type of fogger may be operated with a gas-fired or steam heater if it is desirable.

It is important that the gas pass up through the heater and that the thermoregulator controlling the gas temperatures be located at the top of the heater. With this arrangement, if the gas flow should be interrupted, heat from the heating elements will rise and the thermoregulator will cut off the current. As a further safety measure, we have employed two thermoregulators connected in series and arranged so that if the controlling regulator should fail, the second will operate at a temperature 50°F higher.

The temperature of the gas at this point is usually maintained at 350° to 400°F. However, it has been determined that temperatures as high as 500°F may be employed without decomposition of gas or oil. Use of higher temperatures permits increasing fogging rates substantially.

In passing up through the tower packing, counter-current to the oil flow, the hot gas heats and vaporizes the oil. The gas should leave the top of the tower at temperatures of 300 to 400°F, depending upon the boiling range of the fogging oil.

From this point the hot gas with oil vapor passes through an insulated line to the main gas stream where it is rapidly cooled by

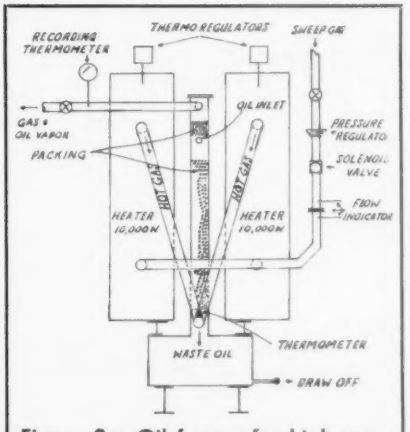

Figure 2. Oil fogger for high pressure stations designed to fog 10 gals. of oil per day. Sweep gas 5,000-6,000 cu. ft. per hr. Designed to operate at 150 psig and 400°F.

mixing with the cold gas, thus producing a stable fog. It is important that this line should be as short as possible. If a long line is required, heat should be added in order to prevent cooling of sweep gas and the condensation of oil vapor.

Approximately three inches of packing are placed in the tower above the point of introduction of the oil to reduce to the minimum the quantity of unvaporized oil carried in the gas stream.

The fogging rate is controlled by the rate at which oil is delivered to the tower.

We have followed the practice of supplying the oil by means of a small controlled volume pump equipped for adjustable feed rates.

Fresh oil is added continuously to the vaporizing tower and the unvaporized residue is collected in a reservoir at the bottom, out of contact with the gas stream. Not more than 80 to 90 per cent of the oil added should be vaporized in order that the residue may remain fluid and drain readily from the tower packing. The percentage of the oil vaporized may be controlled by either changing the sweep gas rate or the operating temperature.

The second drawing shows a fogger of the same type which was, however, designed for a distribution system operating at 100 to 120 psig.

The seven-fold increase in gas pressure requires the use of approximately seven times the quantity of sweep gas to secure the same oil vaporization rate as that obtained in a low pressure fogger.

The third drawing shows a large oil fogger designed for use at our principal distribution center where steam is readily available.

In this installation the sweep gas is heated by steam in a heat exchanger. In this design the oil is atomized into free space between layers of Raschig rings. This arrangement was used because we thought that the residue from the larger volume of oil for which this fogger was designed might clog a thick bed of tower packing. Experience has shown this precaution was not necessary.

The sweep gas rate has been about 20,000 cubic feet per hour and the oil fogged has averaged 50 to 60 gallons per day. During the past winter this fogger operated continuously without a single interruption. The oil residue drained from the bottom has been held at 20 to 25 per cent of that added. No solid residues have accumulated in the Raschig rings.

When foggers of this type were first placed in operation, the distance of travel and distribution of the fog were carefully studied.

Distance tests

The last fogger discussed, when placed in operation, was fogging oil at a rate of 50 gallons per day, which was equivalent to ¾ of a gallon of oil per million cubic feet of gas. When oil had appeared at four test points in the distribution system and could be definitely identified as fogging oil, these distances from the fogger were noted:

Northeast test	2.4 miles
North test	8.8 miles
East test	3.9 miles
South test	6.1 miles

Two additional test locations were installed and fogging oil was found:

Northeast test	7.5 miles
West test	5.25 miles

The excellent stability and transit of the fog produced by this equipment are also demonstrated by the fact that only negligible amounts of oil have been found in the mains close to the fogging locations. The excellent control is further demonstrated by the fact that no excessive oil has been found in customer service lines located close to the fogging points.

The fogging oil we use is a paraffin base oil which has been acid washed and distilled. It is made from selected stock to assure stability. Its distillation range is:

1 per cent over	587°F
5	596
20	601
50	610
70	623
90	646
99.3	668

The viscosity of the oil is approximately 50 seconds at 100°F, Saybolt Universal.

It has been our practice to condition new or dry systems with oil fog at a rate of 1½ to 2 gallons of oil per million cubic feet of gas. We believe about one gallon per million is sufficient once the system becomes oil wet.

Because of the high stability and carry of the fog made with this equipment these quantities are usually adequate. Higher fog concentration should be employed with caution because of possible trouble due to oil at customers' appliances.

Summary of results

It has now been more than two years since straight natural gas was first introduced into our system. We have had no evidence of dust movement or trouble in any part of the system and have had no indication of more than the usual negligible leakage from our mains. A further benefit has resulted in that we have experienced only minor difficulty in obtaining sufficient concentration of the mercaptan-type odorant in all parts of our distribution system.

Our experience on several occasions has definitely established the fact that an oil wet system is a "must" for maintaining desired odorant concentration.

Based on these considerations, we believe that our extensive gas conditioning program, which includes humidification as well as oil fogging, has paid dividends in good service and freedom from trouble.

NOTE: Application has been made for letters patent covering the novel features of the apparatus and method described herein. —EDITOR.

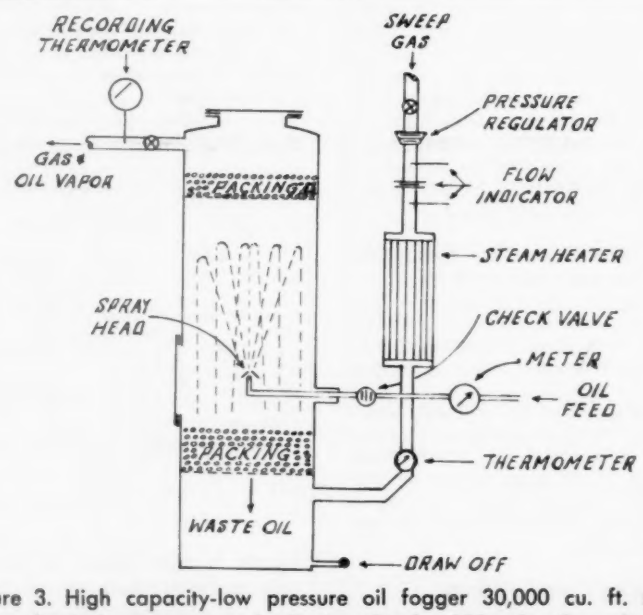

Figure 3. High capacity-low pressure oil fogger 30,000 cu. ft. steam heated sweep gas per hr. Designed to fog 100 gals. oil per day.

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DEFINITIONS OF TERMS

Air

AIR is a mixture of nitrogen, oxygen, water vapor, carbon dioxide, argon, neon and small quantities of other rare gases. For all practical purposes of combustion, air may be said to be composed by volume, of—

Oxygen (O_2)—20.9% Nitrogen (N_2)—79.1%

and by weight of

Oxygen (O_2)—23.15% Nitrogen (N_2)—76.85%

WEIGHT OF AIR at 60° F. is .076 lb. per cubic foot at sea level, atmospheric pressure. One pound of air at 60° F. and at atmospheric pressure has a volume of 13.06 cubic feet.

Annealing

ANNEALING is a process involving heating and cooling applied usually to induce softening. The term is also used to cover treatments intended to: (1) Remove stresses, (2) alter mechanical or physical properties, (3) produce a definite microstructure, and (4) remove gases.

Annealing, Bright

BRIGHT ANNEALING is an annealing process which is usually carried out in a controlled furnace atmosphere so that surface oxidation is reduced to a minimum and the surface remains relatively bright.

Atmosphere, Neutral

NEUTRAL ATMOSPHERE in a furnace or heating operation is, as the name suggests, neither oxidizing nor reducing, and indicates a state of perfect combustion. For a given high temperature heating furnace this type of atmosphere is usually the ideal and represents maximum fuel economy in combustion.

Atmosphere, Oxidizing

OXIDIZING ATMOSPHERE in a furnace or heating operation means an atmosphere in which there is an excess of oxygen or air present. Sometimes it is desired to have such an atmosphere to aid certain chemical reactions. In most cases of furnace heating this type of atmosphere results in waste of fuel and scaling of the work. Also, in some cases, an oxidizing atmosphere exists because it has been necessary to reduce the flame temperature by dilution with cold air for low temperature operations.

Atmosphere, Reducing

REDUCING ATMOSPHERE in a furnace or heating operation means an atmosphere in which there is a deficiency of oxygen or air to complete the process of combustion. Such an atmosphere is deliberately produced in some operations to aid certain chemical reactions or to preclude scaling or oxidizing of the work. In most cases of furnace heating excessive reducing atmosphere causes a waste of unconsumed fuel and a lowering of furnace temperature.

British Thermal Unit

THE BRITISH THERMAL UNIT (Btu) is 1/180 of the heat required to raise the temperature of one pound of water from 32° F. to 212° F. Formerly it was defined as the quantity of heat required to raise one pound of water from 62° F. to 63° F. A common nontechnical definition is the amount of heat required to raise the temperature of one pound of water one degree F.

Carburizing

CARBURIZING is a process in which carbon is introduced into a solid iron-base alloy by heating above the transformation temperature range while in contact with a carbonaceous material which may be a solid, liquid, or gas. Carburizing is frequently followed by quenching to produce a hardened case.

Casehardening

CASEHARDENING is a process of surface hardening involving a change in the composition of the outer layer of an iron-base alloy followed by appropriate thermal treatment. Typical caseheardening processes are Carburizing, Cyaniding, Carbonitriding, and Nitriding.

Combustion, Complete

COMPLETE COMBUSTION is the complete oxidation of a fuel regardless of whether or not this is accomplished with an excess amount of oxygen.

Combustion, Perfect

PERFECT COMBUSTION is the complete oxidation of a fuel with exactly the theoretical amount of oxygen required.

Conduction

CONDUCTION is the process of diffusion or flow of heat energy through a mass or body of matter by particle or molecular contact from the warmer to the colder parts. Thus, heat applied to one end of an iron bar will be conducted to the other end from particle to particle within the iron bar.

Convection

CONVECTION is the process of heating a substance by the motion of warmer fluids or gases in contact with the substance. Thus, water tubes in a boiler may be heated by means of the hot products of combustion sweeping over them. The surfaces of the boiler tubes thus heated by convection then *conduct* the heat through the metal of the tubes to the inner surface in contact with the water where the heat is transferred by a combination of conduction and convection to the water.

Cubic Foot, Standard

THE STANDARD CUBIC FOOT is the quantity of gas saturated with water vapor which at a temperature of 60° F. and a pressure of 30 inches of mercury occupies one cubic foot.

This is the standard cubic foot universally used by the manufactured gas industry.

In the natural gas industry, however, gas volumes are usually calculated on a dry basis at a temperature of 60° F. and a specified base pressure.

Degree Day

DEGREE DAY is a term used to express the intensity of the heating season. It is the difference between 65° F. and the daily mean temperature. The sum of these differences for every day of the heating season is the total degree days for the year. Experience has shown that the gas heating season starts when the monthly mean temperature is 65° F., and that gas consumption for house heating is proportional to the drop in temperature below 65° F.

Gas Conditions, Standard

	Manufactured Gas	*Natural Gas*
Gas temperature	60° F.	60° F.
Gas pressure	30 inches of mercury	As per contract
Water vapor in gas	Saturated at 60° F.	Usually dry

Heating Value, Gross

THE GROSS HEATING VALUE of a fuel is the total Btu liberated by complete combustion when the products of combustion are cooled to the temperature of the atmosphere and the water vapor in the products of combustion is condensed to a liquid.

Heating Value, Net

THE NET HEATING VALUE of a fuel is the amount of heat in Btu's which would be available from complete combustion per unit of fuel if the products of combustion were cooled to 212° F. and the water vapor remained as a gas.

THE NET HEATING VALUE of a fuel is equal to the gross heating value minus the latent heat of vaporization of the water vapor present in the products of combustion.

THE NET HEATING VALUE is not determined directly, but is calculated from the gross heating value. The difference between the gross and net heating values is 1122 Btu's per pound of water in the products of combustion. In the case of natural gas, this difference amounts to, roughly, 100 Btu's, while for manufactured gas it is approximately 50 Btu's per cubic foot.

In American gas practice heat standards and appliance efficiencies are based on the gross heating value.

Kilogram Calorie

THE KILOGRAM CALORIE (large calorie) is 1/100 of the heat required to raise the temperature of one kilogram of water from 0° C. to 100° C. A kilogram calorie therefore is equal to 1.8 x 2.2046, or 3.968 Btu's.

Pressure, Absolute

ABSOLUTE PRESSURE is the sum of the gauge pressure and the atmospheric pressure. For example, for gas at 100 lbs. gauge pressure, the absolute pressure at sea level would be 100 + 14.7 = 114.7 lbs.

Load Factor

LOAD FACTOR is the ratio of average daily gas sendout to peak day sendout during a given time interval, usually a year.

Pressure, Atmospheric

ATMOSPHERIC PRESSURE is the pressure at the atmosphere at some definite elevation. At sea level it is 14.7 lbs. per square inch or 760 m.m. (30 inches) of mercury.

Pressure, Critical

CRITICAL PRESSURE is the pressure at which a gas may be liquefied at the critical temperature.

Radiation

RADIATION is the process of heat transmission by heat waves through the air or other gases, an example of which is the sun's rays heating the earth.

Temperature, Absolute

ABSOLUTE TEMPERATURE is the temperature reckoned from the absolute zero.

Temperature, Critical

CRITICAL TEMPERATURE is the temperature above which a gas cannot be liquefied by pressure alone.

Temperature, Ignition

IGNITION TEMPERATURE is the lowest temperature at which a substance can be ignited.

Tempering

TEMPERING is a process of reheating hardened or normalized steel to a temperature below the transformation temperature, range, followed by any desired rate of cooling.

Therm

A THERM is 100,000 Btu's.

Vaporization, Latent Heat of

LATENT HEAT OF VAPORIZATION of a substance is the quantity of heat required to change it from liquid to vapor without raising its temperature.

Zero, Absolute

ABSOLUTE ZERO is the temperature at which a gas would show no pressure if the general law for gases should hold for all temperatures. It is equal to —273.18° C. or —459.72° F.

English Weights and Measures

Length

1000 mils = 1 inch
12 inches = 1 foot
3 feet = 1 yard
5280 feet = 1 mile
4 inches = 1 hand
9 inches = 1 span
2½ feet = 1 pace
16½ feet or 5½ yards = 1 rod
1 knot or nautical mile = 6080.26 feet = 1/3 league
7.92 inches = 1 link
25 links = 1 rod
100 links or 66 feet or 4 rods = 1 chain
10 chains = 1 furlong
8 furlongs = 1 mile

Surface

144 square inches = 1 square foot
9 square feet = 1 square yard
30¼ square yards = 1 square rod
160 square rods = 1 acre
640 acres = 1 square mile
625 square links = 1 square rod
16 square rods = 1 square chain
10 square chains = 1 acre
640 acres = 1 square mile
36 square miles = 1 township

Volume

1728 cubic inches = 1 cubic foot
27 cubic feet = 1 cubic yard
128 cubic feet = 1 cord
24¾ cubic feet = 1 perch

Troy Weight

24 grains (gr.) = 1 pennyweight (dwt.)
20 pennyweights = 1 ounce (oz.)
12 ounces = 1 pound (lb.)

Avoirdupois Weight

16 drams (dr.) = 1 ounce (oz.)
16 ounces = 1 pound (lb.)
25 pounds = 1 quarter (qr.)
4 quarters = 1 hundred weight (cwt.)
20 hundred weight (2000 pounds) = 1 ton (T.)

Apothecaries' Weight

20 grains (gr.) = 1 scruple (sc. or)
3 scruples = 1 dram (dr.or)
8 drams = 1 ounce (oz. or)
12 ounces = 1 pound (lb)

Dry Measure

2 pints (pt.) = 1 quart (qt.)
8 quarts = 1 peck (pk.)
4 pecks = 1 bushel (bu.)
36 bushels = 1 chaldron (ch.)

Liquid Measure

4 gills (gi.) = 1 pint (pt.)
2 pints = 1 quart (qt.)
4 quarts = 1 gallon (gal.)
31½ gallons = 1 barrel (bar.)
63 gallons = 1 hogshead (hhd.)

Apothecaries' Fluid Measure

60 minims = 1 fluid-drachm
8 fluid-drachms = 1 fluid-ounce
16 fluid-ounces = 1 pint
8 pints = 1 gallon

Circular Measure

60 seconds (″) = 1 minute (′)
60 minutes = 1 degree (°)
30 degrees = 1 sign (s)
12 signs, or 360 degrees = 1 circle (cir.)

THE METRIC SYSTEM

(Extract from tables of equivalents published by the Department of Commerce and Labor, Bureau of Standards.)

The fundamental unit of the metric system is the METER (the unit of length).

From this the units of mass (GRAM) and capacity (LITER) are derived.

All other units are the decimal subdivisions or multiples of these. These three units are simply related, so that for all practical purposes the volume of one kilogram of water (one liter) is equal to one cubic decimeter.

Prefixes	Meaning			Units
Milli-	= one thousandth	$\frac{1}{1000}$	.001	
Centi-	= one hundredth	$\frac{1}{100}$	.01	METER for length
Deci-	= one tenth	$\frac{1}{10}$	.1	
unit	= one		1.	GRAM for mass
Deka-	= ten	$\frac{10}{1}$	10.	
Hecto-	= one hundred	$\frac{100}{1}$	100.	LITER for capacity
Kilo-	= one thousand	$\frac{1000}{1}$	1000.	

The metric terms are formed by combining the words "Meter," "Gram" and "Liter" with the six numerical prefixes.

Length

10 milli-meters (mm)	= 1 centi-meter (cm).
10 centi-meters	= 1 deci-meter (dm).
10 deci-meters	= 1 METER (about 40 inches) (m).
10 meters	= 1 deka-meter (dkm).
10 deka-meters	= 1 hecto-meter (hm).
10 hecto-meters	= 1 kilo-meter (about ⅝ mile) (km).

Mass

10 milli-grams (mg)	= 1 centi-gram (cg).
10 centi-grams	= 1 deci-gram (dg).
10 deci-grams	= 1 GRAM (about 15 grains) (g).
10 grams	= 1 deka-gram (dkg).
10 deka-grams	= 1 hecto-gram (hg).
10 hecto-grams	= 1 kilo-gram (about 2 pounds) (kg).

Capacity

10 milli-liters (ml)	= 1 centi-liter (cl).
10 centi-liters	= 1 deci-liter (dl).
10 deci-liters	= 1 liter (about 1 quart) (1).
10 liters	= 1 deka-liter (dkl).
10 deka-liters	= 1 hecto-liter (about a barrel) (hl).
10 hecto-liters	= 1 kilo-liter (kl).

The square and cubic units are the squares and cubes of the linear units.

The ordinary unit of land area is the Hectare (about 2½ acres).

For ordinary mental comparison it is convenient to know the approximate relations; e.g., 1 meter = 40 inches; 3 decimeters = 1 foot; 1 decimeter = 4 inches; 1 liter = 1 liquid quart; 1 kilogram = 2⅕ pounds; 30 grams = 1 avoirdupois ounce; 1 metric ton = 1 gross ton (see tables).

Equivalents

All lengths, areas and cubic measures in the following tables are derived from the international meter, the legal equivalent being 1 METER = 39.37 INCHES (law of July 28, 1866). In 1893 the United States Office of Standard Weights and Measures was authorized to derive the yard from the meter, using for the purpose the relation legalized in 1866, 1 YARD EQUALS $\frac{3600}{3937}$ METER. The customary weights are likewise referred to the kilogram. (Executive order approved April 5, 1893.) This action fixed the values, inasmuch as the reference standards are as perfect and unalterable as it is possible for human skill to make them.

All capacities are based on the practical equivalent 1 cubic decimeter equals 1 liter. The decimeter is equal to 3.937 inches in accordance with the legal equivalent of the meter given above. The gallon referred to in the tables is the United States gallon of 231 cubic inches. The bushel is the United States bushel of 2150.42 cubic inches. These units must not be confused with the British units of the same name, which differ from those used in the United States. The British gallon is approximately 20 per cent larger, and the British bushel 3 per cent larger, than the corresponding units used in this country.

The customary weights derived from the international kilogram are based on the value 1 avoirdupois pound = 453.5924277 grams. This value is carried out farther than that given in the law, but is in accord with the latter as far as it is there given. The value of the troy pound is based upon the relation just mentioned, and also the equivalent $\frac{5760}{7000}$ avoirdupois pound equals 1 troy pound.

Length

Centimeter	= 0.3937 inch.
Meter	= 3.28 feet.
Meter	= 1.094 yards.
Kilometer	= 0.621 statute mile.
Kilometer	= 0.5396 nautical mile.
Inch	= 2.540 centimeters.
Foot	= 0.305 meter.
Yard	= 0.914 meter.
Statute mile	= 1.61 kilometers.
Nautical mile	= 1.853 kilometers.

Area

Square centimeter	= 0.155 square inch.
Square meter	= 10.76 square feet.
Square meter	= 1.196 square yards.
Hectare	= 2.47 acres.
Square kilometer	= 0.386 square mile.
Square inch	= 6.45 square centimeters.
Square foot	= 0.0929 square meter.
Square yard	= 0.836 square meter.
Acre	= 0.405 hectare.
Square mile	= 2.59 square kilometers.

Volume

Cubic centimeter	= 0.0610 cubic inch.
Cubic meter	= 35.3 cubic feet.
Cubic meter	= 1.308 cubic yards.
Cubic inch	= 16.39 cubic centimeters.
Cubic foot	= 0.0283 cubic meter.
Cubic yard	= 0.765 cubic meter.

Capacity

Milliliter	= 0.0338 U. S. liquid ounce.
Milliliter	= 0.2705 U. S. apothecaries' dram.
Liter	= 1.057 U. S. liquid quarts.
Liter	= 0.2642 U. S. liquid gallon.
Liter	= 0.908 U. S. dry quart.
Dekaliter	= 1.135 U. S. pecks.
Hectoliter	= 2.838 U. S. bushels.
U. S. liquid ounce	= 29.57 milliliters.
U. S. apothecaries' dram	= 3.70 milliliters.
U. S. liquid quart	= 0.946 liter.
U. S. dry quart	= 1.101 liters.
U. S. liquid gallon	= 3.785 liters.
U. S. peck	= 0.881 dekaliter.
U. S. bushel	= 0.3524 hectoliter.

Weight

Gram	= 15.43 grains.
Gram	= 0.772 U. S. apothecaries' scruple.
Gram	= 0.2572 U. S. apothecaries' dram.
Gram	= 0.0353 avoirdupois ounce.
Gram	= 0.03215 troy ounce.
Kilogram	= 2.205 avoirdupois pounds.
Kilogram	= 2.679 troy pounds.
Metric ton	= 0.984 gross or long ton.
Metric ton	= 1.102 short or net tons.
Grain	= 0.0648 gram.
U. S. apothecaries' scruple	= 1.296 grams.
U. S. apothecaries' dram	= 3.89 grams.
Avoirdupois ounce	= 28.35 grams.
Troy ounce	= 31.10 grams.
Avoirdupois pound	= 0.4536 kilogram.
Troy pound	= 0.373 kilogram.
Gross or long ton	= 1.016 metric tons.
Short or net ton	= 0.907 metric ton.

PRESSURE CONVERSION TABLE
Dynes
Pounds
Pounds
Ounces
Ounces
Grams

PRESSURE CONVERSION TABLE

	Centimeters of water at 4°C	Inches of water at 4°C	Feet of water at 4°C	Centimeters of mercury	Inches of mercury	Grams per square centimeter	Ounces per square inch	Ounces per square foot	Pounds per square inch	Pounds per square foot	Dynes per square centimeter	Normal atmosphere	45° latitude atmosphere
Centimeters of water at 4°C	1.000000	0.3937000	0.03280833	0.07355393	0.02895818	0.9999730	0.2275682	32.76983	0.01422301	2.048114	980.6385	0.$_3$9678148	0.$_3$9678632
Inches of water at 4°C	2.540005	1.000000	0.08333333	0.1868273	0.07355393	2.539936	0.5780245	83.23552	0.03612653	5.202220	2490.827	0.002458255	0.002458377
Feet of water at 4°C	30.48006	12.00000	1.000000	2.241928	0.8826471	30.47924	6.936294	998.8263	0.4335183	62.42664	29889.92	0.02949906	0.02950053
Centimeters of mercury	13.59547	5.352535	0.4460446	1.000000	0.3937000	13.59510	3.093896	445.5211	0.1933685	27.84507	13332.24	0.01315789	0.01315855
Inches of mercury	34.53255	13.59547	1.132956	2.540005	1.000000	34.53162	7.858513	1131.626	0.4911570	70.72661	33863.95	0.03342112	0.03342279
Grams per square centimeter	1.000027	0.3937106	0.03280922	0.07355591	0.02895896	1.000000	0.2275744	32.77071	0.01422340	2.048169	980.6650	0.$_3$9678410	0.$_3$9678893
Ounces per square inch	4.394286	1.730031	0.1441692	0.3232170	0.1272505	4.394168	1.000000	144.0000	0.06250000	9.000000	4309.207	0.004252856	0.004253068
Ounces per square foot	0.03051588	0.01201410	0.001001175	0.002244563	0.$_3$8836843	0.03051505	0.006944444	1.000000	0.$_4$340278	0.06250000	29.92505	0.$_2$9533372	0.$_2$9533520
Pounds per square inch	70.30858	27.68049	2.306707	5.171473	2.036009	70.30669	16.00000	2304.000	1.000000	144.0000	68947.31	0.06804569	0.06804909
Pounds per square foot	0.4882541	0.1922256	0.01601880	0.03591300	0.01413895	0.4882409	0.1111111	16.00000	0.006944444	1.000000	478.8007	0.$_4$725395	0.$_4$725631
Dynes per square centimeter	0.001019744	0.$_4$4014731	0.$_3$3345609	0.$_4$7500616	0.$_2$2962992	0.001019716	0.$_5$2320613	0.03341682	0.$_4$1450383	0.002088552	1.000000	0.$_9$9869231	0.$_9$9869724
Normal atmosphere	1033.255	406.7927	33.89939	76.00000	29.92130	1033.228	235.1361	33859.60	14.69601	2116.225	1013250.	1.000000	1.000050
45° latitude atmosphere	1033.204	406.7724	33.89770	75.99620	29.91970	1033.176	235.1244	33857.91	14.69527	2116.119	1013200	0.9999500	1.000000

Expressions like 0.0$_3$ and 0.0$_6$ stand for 0.000 and 0.000000.

This table is based on the following values and definitions from I.C.T.:

Standard acceleration of gravity, 980.665 cm per second per second. 1 l = 1000.027 cc, 1 cm = 0.3937 in.

[1] Adapted from *K. C. Testing Lab. Bull.* 25.

45° latitude acceleration of gravity, 980.616 cm per second per second, 1 lb = 453.5924277 g, 1 normal atmosphere = pressure exerted on 1 sq cm by a vertical column of liquid 76 cm in height, of density 13.5951 g per cubic centimeter, at a place where the acceleration of gravity is standard.

45° latitude atmosphere differs from the normal atmosphere only in the value of gravity.

Adapted from "International Critical Table," McGraw-Hill Book Co.

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CONVERSION FACTORS FOR ENERGY UNITS

Acceleration of gravity = 980.665 cm per second per second

Units	Btu	Pcu[2]	Calories (large)	Foot-pounds	Foot-tons	Kilogram-meters	Horsepower-hours	Kilowatt-hours	Joules, international	Pounds carbon[2]	Pounds water[2]
Btu	1.00000	0.555556	0.251983	777.979	0.388990	107.560	0.0$_3$92922	0.0$_3$93000	1,054.46	0.0$_4$87569	0.00103050
Pcu[2]	1.80000	1.00000	0.453569	1,400.36	0.700181	193.607	0.0$_3$707260	0.0$_3$527400	1,898.03	0.0$_3$123762	0.00185490
Calories (large)	3.96852	2.20474	1.00000	3,087.43	1.54372	426.853	0.00155932	0.00116278	4,184.66	0.0$_3$272863	0.00408958
Foot-pounds	0.00128538	0.0$_3$714101	0.0$_3$323894	1.00000	0.0$_3$500000	0.138255	0.0$_5$505051	0.0$_3$376617	1.35539	0.0$_6$883788	0.0$_3$132459
Foot-tons	2.57076	1.42820	0.647788	2,000.00	1.00000	276.510	0.00101010	0.0$_3$753233	2,710.77	0.0$_3$176758	0.00264918
Kilogram-meters	0.00929716	0.00516509	0.00234272	7.23300	0.00361650	1.00000	0.0$_3$65306	0.0$_3$72407	9.80351	0.0$_5$639244	0.0$_3$95807$_6$
Horsepower-hours	2,545.03	0.141391	641.304	1,979,980	989.999	273,743	1.00000	0.745694	2,683,640	0.174988	2.62266
Kilowatt-hours	3,412.97	1,896.09	860.009	2,655,220	1,327.61	367,098	1.34103	1.00000	3,598,850	0.234665	3.51707
Joules (international)	0.0$_3$948350	0.0$_3$526861	0.0$_3$238968	0.737797	0.0$_3$368898	0.102004	0.0$_3$72628	0.0$_3$277807	1.00000	0.0$_6$52056	0.0$_3$977278
Pounds carbon[2]	14,544	808.000	3,664.84	11,314,900	5,657.47	1,564,350	5.71466	4.26139	15,336,100	1.00000	14.9876
Pounds water[2]	970.40	539.111	244.524	754,951	377.476	104,376	0.381292	0.284327	1,023,250	0.0667217	1.00000

This table is based upon the following I.C.T. values:

1 Btu (mean)	= 1054.8	absolute joules
1 g-cal (mean)	= 4.186	absolute joules
1 ft-lb	= 1.35582	absolute joules
1 kg-m	= 9.80665	absolute joules
1 hp-hr	= 2.6845 × 10^6	absolute joules
1 kwhr	= 3.6000 × 10^6	absolute joules
1 international joule	= 1.00032	absolute joules

[1] Adapted from Van Nostrand's "Chemical Annual" and I.C.T.:

[2] Pcu refers to pound-Centigrade unit. The ton used is 2000 lb. "Pounds carbon" refers to pounds of carbon oxidised to CO_2 of 100 per cent efficiency equivalent to the corresponding number of heat units. "Pounds water" refers to pounds of water evaporated at 212°F at 100 per cent efficiency.

0.0$_3$ signifies 0.000.

1 cal (small) per gram = 1.8 Btu per pound.

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TEMPERATURE CONVERSION TABLE

°C	0	10	20	30	40	50	60	70	80	90
	F	F	F	F	F	F	F	F	F	F
−200	−328	−346	−364	−382	−400	−418	−436	−454	-----	-----
−100	−148	−166	−184	−202	−220	−238	−256	−274	−292	−310
−0	+32	+14	−4	−22	−40	−58	−76	−94	−112	−130
0	32	50	68	86	104	122	140	158	176	194
100	212	230	248	266	284	302	320	338	356	374
200	392	410	428	446	464	482	500	518	536	554
300	572	590	608	626	644	662	680	698	716	734
400	752	770	788	806	824	842	860	878	896	914
500	932	950	968	986	1004	1022	1040	1058	1076	1094
600	1112	1130	1148	1166	1184	1202	1220	1238	1256	1274
700	1292	1310	1328	1346	1364	1382	1400	1418	1436	1454
800	1472	1490	1508	1526	1544	1562	1580	1598	1616	1634
900	1652	1670	1688	1706	1724	1742	1760	1778	1796	1814
1000	1832	1850	1868	1886	1904	1922	1940	1958	1976	1994
1100	2012	2030	2048	2066	2084	2102	2120	2138	2156	2174
1200	2192	2210	2228	2246	2264	2282	2300	2318	2336	2354
1300	2372	2390	2408	2426	2444	2462	2480	2498	2516	2534
1400	2552	2570	2588	2606	2624	2642	2660	2678	2696	2714
1500	2732	2750	2768	2786	2804	2822	2840	2858	2876	2894
1600	2912	2930	2948	2966	2984	3002	3020	3038	3056	3074
1700	3092	3110	3128	3146	3164	3182	3200	3218	3236	3254
1800	3272	3290	3308	3326	3344	3362	3380	3398	3416	3434
1900	3452	3470	3488	3506	3524	3542	3560	3578	3596	3614
2000	3632	3650	3668	3686	3704	3722	3740	3758	3776	3794
2100	3812	3830	3848	3866	3884	3902	3920	3938	3956	3974
2200	3992	4010	4028	4046	4064	4082	4100	4118	4136	4154
2300	4172	4190	4208	4226	4244	4262	4280	4298	4316	4334
2400	4352	4370	4388	4406	4424	4442	4460	4478	4496	4514
2500	4532	4550	4568	4586	4604	4622	4640	4658	4676	4694
2600	4712	4730	4748	4766	4784	4802	4820	4838	4856	4874
2700	4892	4910	4928	4946	4964	4982	5000	5018	5036	5054
2800	5072	5090	5108	5126	5144	5162	5180	5198	5216	5234
2900	5252	5270	5288	5306	5324	5342	5360	5378	5396	5414
3000	5432	5450	5468	5486	5504	5522	5540	5558	5576	5594
3100	5612	5630	5648	5666	5684	5702	5720	5738	5756	5774
3200	5792	5810	5828	5846	5864	5882	5900	5918	5936	5954
3300	5972	5990	6008	6026	6044	6062	6080	6098	6116	6134
3400	6152	6170	6188	6206	6224	6242	6260	6278	6296	6314
3500	6332	6350	6368	6386	6404	6422	6440	6458	6476	6494
3600	6512	6530	6548	6566	6584	6602	6620	6638	6656	6674
3700	6692	6710	6728	6746	6764	6782	6800	6818	6836	6854
3800	6872	6890	6908	6926	6944	6962	6980	6998	7016	7034
3900	7052	7070	7088	7106	7124	7142	7160	7178	7196	7214
°C	0	10	20	30	40	50	60	70	80	90

°C	°F
1	1. 8
2	3. 6
3	5. 4
4	7. 2
5	9. 0
6	10. 8
7	12. 6
8	14. 4
9	16. 2
10	18. 0

°F	°C
1	0. 56
2	1. 11
3	1. 67
4	2. 22
5	2. 78
6	3. 33
7	3. 89
8	4. 44
9	5. 00
10	5. 56
11	6. 11
12	6. 67
13	7. 22
14	7. 78
15	8. 33
16	8. 89
17	9. 44
18	10. 00

EXAMPLES: 1347° C = 2444° F + 12.6° F = 2456.6° F. 3367° F = 1850° C + 2.78° C = 1852.78° C.

Bureau of Standards—M126

No.	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396
No.	0	1	2	3	4	5	6	7	8	9

No.	0	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996
No.	0	1	2	3	4	5	6	7	8	9

$\text{Log.}_{\pi} = .49715 \quad \text{Log.}_{e} = 2.302585 \times \text{Log.}_{10}$

AREAS OF SURFACES

Triangle = ½ base × perpendicular height.

Parallelogram = base × perpendicular height.

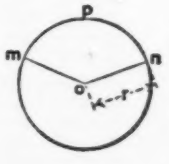
Trapezoid = ½ sum of parallel sides × perpendicular height.

Trapezium—(Divide into two triangles.)

Circle = .7854 × diameter squared or 3.1416 × radius squared.

Ellipse = .7854 × long diameter × short diameter.

Circular Sector, m o n p



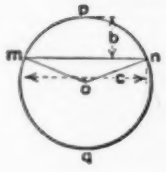
Area = ½ (length of arc, m p n × radius, r)

= area of circle × arc, m p n, in degrees / 360

= 0.0087266 × square of radius, r^2 × angle of arc, m p n, in degrees

Circular Segment, m p n

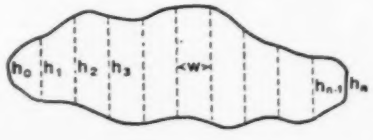
$$\text{Area} = \frac{r^2}{2}\left(\frac{\pi \times \text{angle m p n}}{180} - \text{sin of angle m p n}\right)$$



Irregular Plane Surface

Divide figure into n strips by equidistant parallel lines h_0, h_1, h_n, etc.

$$\text{Area} = W[\tfrac{1}{2}(h_0 + h_n) + (h_1 + h_2 + h_3 + \cdots - h_{n-1})]$$



SURFACE AND VOLUME OF SOLIDS

Parallelopiped, Prism or Cylinder.

Surface. The lateral or convex surface = perimeter of section perpendicular to sides × slant height, or perimeter of base × perpendicular height between bases.

To this add the area of the two ends when this is required.

Volume = area of section perpendicular to sides × slant height, or area of base × perpendicular height between bases.

Pyramid or Cone, Right and Regular.

Surface. The lateral or convex surface = ½ perimeter of base × slant height. (Slant height of a pyramid is taken along one of the edges or corners.) Add area of base where this is required.

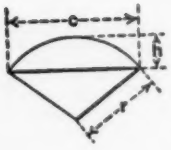
Pyramid or Cone. (Any pyramid or cone.)

Volume = ⅓ area of base × perpendicular height from base to apex.

SPHERE

$$\text{Surface} = \pi d^2 = 4\pi r^2$$

$$\text{Volume} = \frac{\pi d^3}{6} = \frac{4}{3}\pi r^3$$

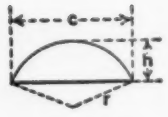


SPHERICAL SECTOR

$$\text{Total Surface} = \frac{\pi r}{2}(4h + c)$$

$$\text{Volume} = \frac{2}{3}\pi r^2 h = \frac{2}{3}\pi r^3$$

$$\left(r - \sqrt{r^2 - \frac{c^2}{4}}\right)$$

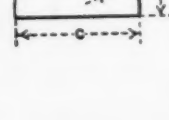


SPHERICAL SEGMENT

$$\text{Spherical Surface} = 2\pi rh = \pi(c^2 + 4h^2) \div 4$$

$$\text{Total Surface} = \text{Spherical Surface} + (\pi c^2 \div 4)$$

$$\text{Volume} = \pi h^2 (3r - h) \div 3 = \pi h\,(3c^2 + 4h^2) \div 24$$



SPHERICAL ZONE

$$\text{Convex Surface} = 2\pi rh$$

$$\text{Total Surface} = 2\pi rh + \frac{\pi}{4}(c^2 + c'^2)$$

$$\text{Volume} = \frac{\pi h}{24}(3c^2 + 3c'^2 + 4h^2)$$

PRISMOID

End faces are in parallel planes

$$\text{Volume} = \frac{l}{6}(A + A' + 4M),$$

where

l = perpendicular distance between ends

A, A' = areas of ends

M = area of mid section parallel to ends

CIRCUMFERENCES AND AREAS OF CIRCLES FROM ⅛ TO 20

Diam.	Circum.	Area	Diam.	Circum.	Area
⅛	.3927	.012272	10	31.416	78.54
¼	.7854	.049087	10⅛	31.8087	80.5158
⅜	1.1781	.110447	10¼	32.2014	82.5161
½	1.5708	.19635	10⅜	32.5941	84.5409
⅝	1.9635	.306796	10½	32.9868	86.5903
¾	2.3562	.441787	10⅝	33.3795	88.6643
⅞	2.7489	.601322	10¾	33.7722	90.7628
1	3.1416	.7854	10⅞	34.1649	92.8858
1⅛	3.5343	.99402	11	34.5576	95.0334
1¼	3.927	1.2272	11⅛	34.9503	97.2055
1⅜	4.3197	1.4849	11¼	35.343	99.4022
1½	4.7124	1.7671	11⅜	35.7357	101.6234
1⅝	5.1051	2.0739	11½	36.1284	103.8691
1¾	5.4978	2.4053	11⅝	36.5211	106.1394
1⅞	5.8905	2.7612	11¾	36.9138	108.4343
2	6.2832	3.1416	11⅞	37.3065	110.7537
2⅛	6.6759	3.5466	12	37.6992	113.098
2¼	7.0686	3.9761	12⅛	38.0919	115.466
2⅜	7.4613	4.4301	12¼	38.4846	117.859
2½	7.854	4.9087	12⅜	38.8773	120.277
2⅝	8.2467	5.4119	12½	39.27	122.719
2¾	8.6394	5.9396	12⅝	39.6627	125.185
2⅞	9.0321	6.4918	12¾	40.0554	127.677
3	9.4248	7.0686	12⅞	40.4481	130.192
3⅛	9.8175	7.6699	13	40.8408	132.733
3¼	10.2102	8.2958	13⅛	41.2335	135.297
3⅜	10.6029	8.9462	13¼	41.6262	137.887
3½	10.9956	9.6211	13⅜	42.0189	140.501
3⅝	11.3883	10.3206	13½	42.4116	143.139
3¾	11.781	11.0447	13⅝	42.8043	145.802
3⅞	12.1737	11.7933	13¾	43.197	148.49
4	12.5664	12.5664	13⅞	43.5897	151.202
4⅛	12.9591	13.3641	14	43.9824	153.938
4¼	13.3518	14.1863	14⅛	44.3751	156.7
4⅜	13.7445	15.033	14¼	44.7678	159.485
4½	14.1372	15.9043	14⅜	45.1605	162.296
4⅝	14.5299	16.8002	14½	45.5532	165.13
4¾	14.9226	17.7206	14⅝	45.9459	167.99
4⅞	15.3153	18.6655	14¾	46.3386	170.874
5	15.708	19.635	14⅞	46.7313	173.782
5⅛	16.1007	20.629	15	47.124	176.715
5¼	16.4934	21.6476	15⅛	47.5167	179.673
5⅜	16.8861	22.6907	15¼	47.9094	182.655
5½	17.2788	23.7583	15⅜	48.3021	185.661
5⅝	17.6715	24.8505	15½	48.6948	188.692
5¾	18.0642	25.9673	15⅝	49.0875	191.748
5⅞	18.4569	27.1086	15¾	49.4802	194.828
6	18.8496	28.2744	15⅞	49.8729	197.933
6⅛	19.2423	29.4648	16	50.2656	201.062
6¼	19.635	30.6797	16⅛	50.6583	204.216
6⅜	20.0277	31.9191	16¼	51.051	207.395
6½	20.4204	33.1831	16⅜	51.4437	210.598
6⅝	20.8131	34.4717	16½	51.8364	213.825
6¾	21.2058	35.7848	16⅝	52.2291	217.077
6⅞	21.5985	37.1224	16¾	52.6218	220.354
7	21.9912	38.4846	16⅞	53.0145	223.655
7⅛	22.3839	39.8713	17	53.4072	226.981
7¼	22.7766	41.2826	17⅛	53.7999	230.331
7⅜	23.1693	42.7184	17¼	54.1926	233.706
7½	23.562	44.1787	17⅜	54.5853	237.105
7⅝	23.9547	45.6636	17½	54.978	240.529
7¾	24.3474	47.1731	17⅝	55.3707	243.977
7⅞	24.7401	48.7071	17¾	55.7634	247.45
8	25.1328	50.2656	17⅞	56.1561	250.948
8⅛	25.5255	51.8487	18	56.5488	254.47
8¼	25.9182	53.4563	18⅛	56.9415	258.016
8⅜	26.3109	55.0884	18¼	57.3342	261.587
8½	26.7036	56.7451	18⅜	57.7269	265.183
8⅝	27.0963	58.4264	18½	58.1196	268.803
8¾	27.489	60.1322	18⅝	58.5123	272.448
8⅞	27.8817	61.8625	18¾	58.905	276.117
9	28.2744	63.6174	18⅞	59.2977	279.811
9⅛	28.6671	65.3968	19	59.6904	283.529
9¼	29.0598	67.2008	19⅛	60.0831	287.272
9⅜	29.4525	69.0293	19¼	60.4758	291.04
9½	29.8452	70.8823	19⅜	60.8685	294.832
9⅝	30.2379	72.7599	19½	61.2612	298.648
9¾	30.6306	74.6621	19⅝	61.6539	302.489
9⅞	31.0233	76.5888	19¾	62.0466	306.355
			19⅞	62.4393	310.245
			20	62.832	314.16

NATURAL TRIGONOMETRIC FUNCTIONS

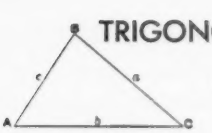
For Angles 0 to 45 Read Down

Degrees	Sines .00° 0′	.25° 15′	.50° 30′	.75° 45′	1.00° 60′	Cosines .00° 0′	.25° 15′	.50° 30′	.75° 45′	1.00° 60′	Degrees
0	0.00000	0.00436	0.00873	0.01309	0.01745	1.00000	0.99999	0.99996	0.99991	0.99985	89
1	0.01745	0.02181	0.02618	0.03054	0.03490	0.99985	0.99976	0.99966	0.99953	0.99939	88
2	0.03490	0.03926	0.04362	0.04798	0.05234	0.99939	0.99923	0.99905	0.99885	0.99863	87
3	0.05234	0.05669	0.06105	0.06540	0.06976	0.99863	0.99839	0.99813	0.99786	0.99756	86
4	0.06976	0.07411	0.07846	0.08281	0.08716	0.99756	0.99725	0.99692	0.99657	0.99619	85
5	0.08716	0.09150	0.09585	0.10019	0.10453	0.99619	0.99580	0.99540	0.99497	0.99452	84
6	0.10453	0.10887	0.11320	0.11754	0.12187	0.99452	0.99406	0.99357	0.99307	0.99255	83
7	0.12187	0.12620	0.13053	0.13485	0.13917	0.99255	0.99200	0.99144	0.99087	0.99027	82
8	0.13917	0.14349	0.14781	0.15212	0.15643	0.99027	0.98965	0.98902	0.98836	0.98769	81
9	0.15643	0.16074	0.16505	0.16935	0.17365	0.98769	0.98700	0.98629	0.98556	0.98481	80
10	0.17365	0.17794	0.18224	0.18652	0.19081	0.98481	0.98404	0.98325	0.98245	0.98163	79
11	0.19081	0.19509	0.19937	0.20364	0.20791	0.98163	0.98079	0.97992	0.97905	0.97815	78
12	0.20791	0.21218	0.21644	0.22070	0.22495	0.97815	0.97723	0.97630	0.97534	0.97437	77
13	0.22495	0.22920	0.23345	0.23769	0.24192	0.97437	0.97338	0.97237	0.97134	0.97030	76
14	0.24192	0.24615	0.25038	0.25460	0.25882	0.97030	0.96923	0.96815	0.96705	0.96593	75
15	0.25882	0.26303	0.26724	0.27144	0.27564	0.96593	0.96479	0.96363	0.96246	0.96126	74
16	0.27564	0.27983	0.28402	0.28820	0.29237	0.96126	0.96005	0.95882	0.95757	0.95630	73
17	0.29237	0.29654	0.30071	0.30486	0.30902	0.95630	0.95502	0.95372	0.95240	0.95106	72
18	0.30902	0.31316	0.31730	0.32144	0.32557	0.95106	0.94970	0.94832	0.94693	0.94552	71
19	0.32557	0.32969	0.33381	0.33792	0.34202	0.94552	0.94409	0.94264	0.94118	0.93969	70
20	0.34202	0.34612	0.35021	0.35429	0.35837	0.93969	0.93819	0.93667	0.93514	0.93358	69
21	0.35837	0.36244	0.36650	0.37056	0.37461	0.93358	0.93201	0.93042	0.92881	0.92718	68
22	0.37461	0.37865	0.38268	0.38671	0.39073	0.92718	0.92554	0.92388	0.92220	0.92050	67
23	0.39073	0.39474	0.39875	0.40275	0.40674	0.92050	0.91879	0.91706	0.91531	0.91355	66
24	0.40674	0.41072	0.41469	0.41866	0.42262	0.91355	0.91176	0.90996	0.90814	0.90631	65
25	0.42262	0.42657	0.43051	0.43445	0.43837	0.90631	0.90446	0.90259	0.90070	0.89879	64
26	0.43837	0.44229	0.44620	0.45010	0.45399	0.89879	0.89687	0.89493	0.89298	0.89101	63
27	0.45399	0.45787	0.46175	0.46561	0.46947	0.89101	0.88902	0.88701	0.88499	0.88295	62
28	0.46947	0.47332	0.47716	0.48099	0.48481	0.88295	0.88089	0.87882	0.87673	0.87462	61
29	0.48481	0.48862	0.49242	0.49622	0.50000	0.87462	0.87250	0.87036	0.86820	0.86603	60
30	0.50000	0.50377	0.50754	0.51129	0.51504	0.86603	0.86384	0.86163	0.85941	0.85717	59
31	0.51504	0.51877	0.52250	0.52621	0.52992	0.85717	0.85491	0.85264	0.85035	0.84805	58
32	0.52992	0.53361	0.53730	0.54097	0.54464	0.84805	0.84573	0.84339	0.84104	0.83867	57
33	0.54464	0.54829	0.55194	0.55557	0.55919	0.83867	0.83629	0.83389	0.83147	0.82904	56
34	0.55919	0.56280	0.56641	0.57000	0.57358	0.82904	0.82659	0.82413	0.82165	0.81915	55
35	0.57358	0.57715	0.58070	0.58425	0.58779	0.81915	0.81664	0.81412	0.81157	0.80902	54
36	0.58779	0.59131	0.59482	0.59832	0.60182	0.80902	0.80644	0.80386	0.80125	0.79864	53
37	0.60182	0.60529	0.60876	0.61222	0.61566	0.79864	0.79600	0.79335	0.79069	0.78801	52
38	0.61566	0.61909	0.62251	0.62592	0.62932	0.78801	0.78532	0.78261	0.77988	0.77715	51
39	0.62932	0.63271	0.63608	0.63944	0.64279	0.77715	0.77439	0.77162	0.76884	0.76604	50
40	0.64279	0.64612	0.64945	0.65276	0.65606	0.76604	0.76323	0.76041	0.75756	0.75471	49
41	0.65606	0.65935	0.66262	0.66588	0.66913	0.75471	0.75184	0.74896	0.74606	0.74314	48
42	0.66913	0.67237	0.67559	0.67880	0.68200	0.74314	0.74022	0.73728	0.73432	0.73135	47
43	0.68200	0.68518	0.68835	0.69151	0.69466	0.73135	0.72837	0.72537	0.72236	0.71934	46
44	0.69466	0.69779	0.70091	0.70401	0.70711	0.71934	0.71630	0.71325	0.71019	0.70711	45
	60′ 1.00°	45′ .75°	30′ .50°	15′ .25°	0′ .00°	60′ 1.00°	45′ .75°	30′ .50°	15′ .25°	0′ .00°	Degrees
	Cosines					Sines					

Degrees	Tangents .00° 0′	.25° 15′	.50° 30′	.75° 45′	1.00° 60′	Cotangents .00° 0′	.25° 15′	.50° 30′	.75° 45′	1.00° 60′	Degrees
0	0.00000	0.00436	0.00873	0.01309	0.01746	Infinity	229.18	114.59	76.390	57.290	89
1	0.01746	0.02182	0.02619	0.03055	0.03492	57.290	45.829	38.188	32.730	28.636	88
2	0.03492	0.03929	0.04366	0.04803	0.05241	28.636	25.452	22.904	20.819	19.081	87
3	0.05241	0.05678	0.06116	0.06554	0.06993	19.081	17.611	16.350	15.257	14.301	86
4	0.06993	0.07431	0.07870	0.08309	0.08749	14.301	13.457	12.706	12.035	11.430	85
5	0.08749	0.09189	0.09629	0.10069	0.10510	11.430	10.883	10.385	9.9310	9.5144	84
6	0.10510	0.10952	0.11394	0.11836	0.12278	9.5144	9.1309	8.7769	8.4490	8.1443	83
7	0.12278	0.12722	0.13165	0.13609	0.14054	8.1443	7.8606	7.5958	7.3479	7.1154	82
8	0.14054	0.14499	0.14945	0.15391	0.15838	7.1154	6.8969	6.6912	6.4971	6.3138	81
9	0.15838	0.16286	0.16734	0.17183	0.17633	6.3138	6.1402	5.9758	5.8197	5.6713	80
10	0.17633	0.18083	0.18534	0.18986	0.19438	5.6713	5.5301	5.3955	5.2672	5.1446	79
11	0.19438	0.19891	0.20345	0.20800	0.21256	5.1446	5.0273	4.9152	4.8077	4.7046	78
12	0.21256	0.21712	0.22169	0.22628	0.23087	4.7046	4.6057	4.5107	4.4194	4.3315	77
13	0.23087	0.23547	0.24008	0.24470	0.24933	4.3315	4.2468	4.1653	4.0867	4.0108	76
14	0.24933	0.25397	0.25862	0.26328	0.26795	4.0108	3.9375	3.8667	3.7983	3.7321	75
15	0.26795	0.27263	0.27732	0.28203	0.28675	3.7321	3.6680	3.6059	3.5457	3.4874	74
16	0.28675	0.29147	0.29621	0.30097	0.30573	3.4874	3.4308	3.3759	3.3226	3.2709	73
17	0.30573	0.31051	0.31530	0.32010	0.32492	3.2709	3.2205	3.1716	3.1240	3.0777	72
18	0.32492	0.32975	0.33460	0.33945	0.34433	3.0777	3.0326	2.9887	2.9459	2.9042	71
19	0.34433	0.34922	0.35412	0.35904	0.36397	2.9042	2.8636	2.8239	2.7852	2.7475	70
20	0.36397	0.36892	0.37388	0.37887	0.38386	2.7475	2.7106	2.6746	2.6395	2.6051	69
21	0.38386	0.38888	0.39391	0.39896	0.40403	2.6051	2.5715	2.5386	2.5065	2.4751	68
22	0.40403	0.40911	0.41421	0.41933	0.42447	2.4751	2.4443	2.4142	2.3847	2.3559	67
23	0.42447	0.42963	0.43481	0.44001	0.44523	2.3559	2.3276	2.2998	2.2727	2.2460	66
24	0.44523	0.45047	0.45573	0.46101	0.46631	2.2460	2.2199	2.1943	2.1692	2.1445	65
25	0.46631	0.47163	0.47698	0.48234	0.48773	2.1445	2.1203	2.0965	2.0732	2.0503	64
26	0.48773	0.49315	0.49858	0.50404	0.50953	2.0503	2.0278	2.0057	1.9840	1.9626	63
27	0.50953	0.51503	0.52057	0.52613	0.53171	1.9626	1.9416	1.9210	1.9007	1.8807	62
28	0.53171	0.53732	0.54296	0.54862	0.55431	1.8807	1.8611	1.8418	1.8228	1.8040	61
29	0.55431	0.56003	0.56577	0.57155	0.57735	1.8040	1.7856	1.7675	1.7496	1.7321	60
30	0.57735	0.58318	0.58905	0.59494	0.60086	1.7321	1.7147	1.6977	1.6808	1.6643	59
31	0.60086	0.60681	0.61280	0.61882	0.62487	1.6643	1.6479	1.6319	1.6160	1.6003	58
32	0.62487	0.63095	0.63707	0.64322	0.64941	1.6003	1.5849	1.5697	1.5547	1.5399	57
33	0.64941	0.65563	0.66189	0.66818	0.67451	1.5399	1.5253	1.5108	1.4966	1.4826	56
34	0.67451	0.68088	0.68728	0.69372	0.70021	1.4826	1.4687	1.4550	1.4415	1.4281	55
35	0.70021	0.70673	0.71329	0.71990	0.72654	1.4281	1.4150	1.4019	1.3891	1.3764	54
36	0.72654	0.73323	0.73996	0.74674	0.75355	1.3764	1.3638	1.3514	1.3392	1.3270	53
37	0.75355	0.76042	0.76733	0.77428	0.78129	1.3270	1.3151	1.3032	1.2915	1.2799	52
38	0.78129	0.78834	0.79544	0.80258	0.80978	1.2799	1.2685	1.2572	1.2460	1.2349	51
39	0.80978	0.81703	0.82434	0.83169	0.83910	1.2349	1.2239	1.2131	1.2024	1.1918	50
40	0.83910	0.84656	0.85408	0.86166	0.86929	1.1918	1.1812	1.1708	1.1606	1.1504	49
41	0.86929	0.87698	0.88473	0.89253	0.90040	1.1504	1.1403	1.1303	1.1204	1.1106	48
42	0.90040	0.90834	0.91633	0.92439	0.93252	1.1106	1.1009	1.0913	1.0818	1.0724	47
43	0.93252	0.94071	0.94896	0.95729	0.96569	1.0724	1.0630	1.0538	1.0446	1.0355	46
44	0.96569	0.97416	0.98270	0.99131	1.00000	1.0355	1.0265	1.0176	1.0088	1.0000	45
	60′ 1.00°	45′ .75°	30′ .50°	15′ .25°	0′ .00°	60′ 1.00°	45′ .75°	30′ .50°	15′ .25°	0′ 00°	Degrees
	Cotangents					Tangents					

For Angles 45 to 90 Read Up

TRIGONOMETRIC FORMULAS



OBLIQUE TRIANGLES

$s = \frac{1}{2}(a+b+c)$

Known	Required	Formulae
A, B, a	C, b	$C = 180° - (A + B)$, $b = \frac{a}{\sin A} \cdot \sin B$
	c	$c = \frac{a}{\sin A} \sin (A + B)$
A, a, b	B, C	$\sin B = \frac{\sin A}{a} \cdot b$, $C = 180° - (A + B)$
	c	$c = \frac{a}{\sin A} \cdot \sin C$
C, a, b	$\frac{1}{2}(A + B)$	$\frac{1}{2}(A + B) = 90° - \frac{1}{2} C$
	$\frac{1}{2}(A - B)$	$\tan \frac{1}{2}(A - B) = \frac{a - b}{a + b} \tan \frac{1}{2}(A + B)$
	A, B	$A = \frac{1}{2}(A + B) + \frac{1}{2}(A - B)$ $B = \frac{1}{2}(A + B) - \frac{1}{2}(A - B)$
	c	$c = (a + b) \frac{\cos \frac{1}{2}(A + B)}{\cos \frac{1}{2}(A - B)}$ $= (a - b) \frac{\sin \frac{1}{2}(A + B)}{\sin \frac{1}{2}(A - B)}$ $= \sqrt{a^2 + b^2 - 2ab \cdot \cos C}$
	area	area $= \frac{1}{2} a b \sin C$.
a, b, c	A	$\sin \frac{1}{2} A = \sqrt{\frac{(s - b)(s - c)}{b c}}$ $\cos \frac{1}{2} A = \sqrt{\frac{s (s - a)}{b c}}$ $\tan \frac{1}{2} A = \sqrt{\frac{(s - b)(s - c)}{s (s - a)}}$ $\sin A = \frac{2 \sqrt{s (s-a)(s-b)(s-c)}}{b c}$ $\text{vers } A = \frac{2 (s - b)(s - c)}{b c}$
	area	area $= \sqrt{s (s - a)(s - b)(s - c)}$
A, B, C, a	area	area $= \frac{a^2 \sin B \cdot \sin C}{2 \sin A}$

COMPOSITION OF AIR

	Dry Air[1]	Percent by Volume Atmospheric Air at Sea Level (Average[2])
Nitrogen	78.03	77.08
Oxygen	20.99	20.75
Argon	.94	.93
Carbon Dioxide	.03	.03
Hydrogen	.01	.01
Water Vapor	—	1.20
Krypton, Neon, Niton, Xenon	Trace	Trace
	100.00	100.00

[1] International Critical Tables.
[2] Guide American Society of Heating and Ventilating Engineers.

MECHANICS OF MATERIALS

Stress is distributed force; its intensity per unit area is generally expressed in pounds per square inch.

The **elastic limit** of a material is the maximum stress in pounds per square inch that will be followed by a complete recovery of form, after the removal of the stress.

Permanent set is the change in form of a member when stressed beyond its elastic limit.

The **ultimate strength** of a material is the least stress in pounds per square inch that will produce rupture.

Modulus of elasticity is the number obtained by dividing the actual stress in pounds per square inch by the corresponding elongation per inch.

The **factor of safety** is the factor obtained by dividing the ultimate strength by the actual stress in pounds per square inch.

Tension and Compression

For direct stress, uniformly distributed,

$$p = \frac{P}{F}$$

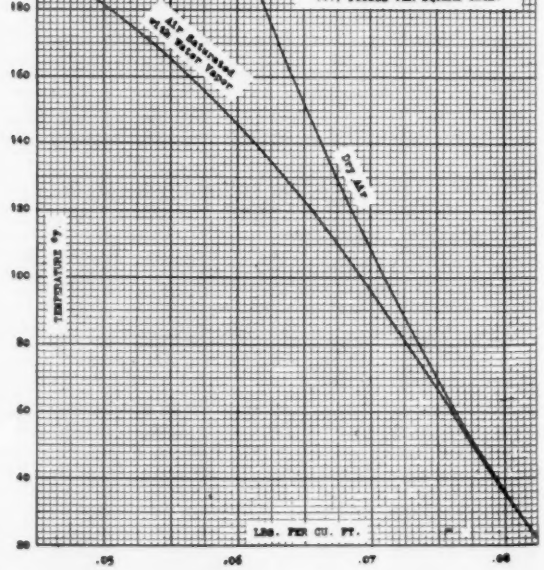
p = stress in pounds per square inch,
P = total load in pounds,
F = cross-sectional area in square inches.

$$E = \frac{p}{\epsilon} \qquad \epsilon = \frac{\lambda}{l}$$

$$E = \frac{\frac{P}{F}}{\frac{\lambda}{l}} = \frac{Pl}{F\lambda}$$

E = modulus of elasticity in tension or compression,
l = length of member in inches,
ϵ = elongation per inch length,
λ = total elongation in inches.

WEIGHT OF DRY AND SATURATED AIR AT DIFFERENT TEMPERATURES IN LBS. PER CU. FT.



DETERMINATION OF HORSEPOWER, TORQUE, ETC.

Horsepower is a unit of mechanical energy or work, and is equal to

33000 ft-lbs per min.
550 ft-lbs per sec.
42.4 Btu per min.

Foot-Pound is a unit of mechanical energy or work, and is the work required to lift one lb. through a vertical distance of one ft.

The Btu (British thermal unit) is equivalent to 778.26 ft. lbs., which is 1/180 part of the heat energy required to raise the temperature of one pound of water from 32° F. to 212° F.

Horsepower-hour is a unit of power, and equals hp. times time in hours of its duration.

Torque is turning effort caused by a force acting normal to a radius at a set distance from the axis of rotation, and is expressed in pound-feet (lbs. at a radius of 1 ft.)—

$$\text{Torque} = \frac{\text{HP}}{\text{RPM}} \times 5250$$

ENGINE HORSEPOWER

Engine horsepower is taken as 33,000 foot-pounds of work in one minute, or 550 foot-pounds of work in one second. To express indicated horsepower the following formula is used:

$$\text{ihp} = \frac{\text{mep LAN}}{33{,}000}$$

Where:

mep is the mean effective pressure (as shown by a steam engine indicator diagram) in pounds per square inch, acting on the piston.
L is the length of the stroke in feet.
A is the area of the piston in square inches (area of the piston rod to be deducted for the crank end).
N is the number of working strokes per minute (in double-acting steam engines it will be twice the number of revolutions).

INDICATED HORSEPOWER OF GAS ENGINES

The same formula is used for this calculation, except that the symbol N represents the total number of explosions per minute in all cylinders.

In computations for four-stroke cycle, single cylinder, single-acting gas engines firing every fourth stroke, this will be the revolutions per minute, divided by two. For two-stroke cycle, single cylinder, single-acting engines, firing every second stroke, or once every revolution, the value of N will be represented by the number of revolutions per minute.

ELECTRICAL HORSEPOWER (INPUT)

The unit for measuring the electrical horsepower input to a motor is the watt. For direct current this is the product of the volts E and the amperes I, measured at the motor terminals, and is represented as $W = EI$. Since 746 watts are equivalent to an electrical horsepower, the following formula represents the above relations:

$$\text{HP} = \frac{EI}{746}$$

Should the power used be taken from an alternating current system, the conditions as outlined below will hold.

If W = watts, E = average volts between terminals, I = average line current, and pf = power factor expressed as a decimal fraction, the following formulae represent their relations:

$$\text{Single phase HP} = \frac{EI \times pf}{746}$$

$$\text{Two phase HP} = \frac{2\,EI \times pf}{746}$$

$$\text{Three phase HP} = \frac{1.732\,EI \times pf}{746}$$

MOTOR SPEED

AC Motors. The synchronous speed of AC motors is determined by the number of poles and frequency.

$$\text{Synchronous speed} = \frac{120 \times \text{f}}{\text{p}}$$

where f = frequency in cycles
p = number of poles of the motor

Induction motors will have full load speeds of from 2 to 6% less than the above, average 4% less.

DC Motors will have standard full-load speeds when hot of: 575, 850, 1150, 1750, and 3500 rev per min (rpm).

At normal temperature, rated load, and voltage the variation above or below the above full-load motor speeds may not exceed 7½% in motors up to 7½ hp at 1150 rpm 5% in motors larger than 7½ hp at 1150 rpm.

ELECTRICAL TERMS

Volt

VOLT is a measure of electrical "pressure" or electro-motive force. Mathematically, it is the product of electrical resistance and electrical current. Volt = Resistance × Current.

Ampere

AMPERE is a practical unit of current and is that current which flows through a conductor having a resistance of 1 ohm and a difference of potential of 1 volt between its ends.

Ohm

OHM is a practical unit of electrical resistance and is that resistance through which the fall of potential is 1 volt when the current strength is 1 ampere.

Watt

WATT is the practical unit of power and is produced when 1 ampere flows under an electromotive force of 1 volt.

Kilowatt Hour

KILOWATT HOUR is the commercial unit of electrical energy and is 1000 watts per hour equivalent to 3412 Btu.

BOILER HORSEPOWER

The equivalent evaporation of 34.5 pounds of water per hour from a feed water temperature of 212 deg F. into steam at the same temperature is a boiler horsepower. Since the actual operating conditions of a boiler are seldom "from and at 212 deg F" a factor is needed to convert the rating from the actual conditions to what they would be "from and at 212 deg." This is called the "factor of evaporation" and equals ratio of the heat required to generate 1 pound of steam under actual conditions to that required to make 1 pound of steam "from and at 212 deg F."

NOTES ON STEAM AND STEAM BOILERS

Steam is perfectly transparent, colorless, dry, and invisible. When partially condensed, as in contact with the air, the mist or spray makes it visible.

Dry steam contains no free moisture. It may be either saturated or superheated.

Wet steam contains free moisture in the form of mist or spray, and has the same temperature as dry saturated steam at the same pressure.

Saturated steam is steam in its normal state. Its temperature is that due to the pressure under which it is formed; that is its temperature is the same as that of the water from which it is generated and upon which it rests.

Superheated steam is steam at a temperature above that due to its pressure being further heated from another source, after leaving the water from which it is generated.

One volume of water evaporated at normal atmospheric pressure and temperature of 212° F. becomes 1603 volumes of steam.

One cu. ft. of steam weighs .03731 lbs., and 1 lb. of steam occupies 26.80 cu. ft., at a pressure of 14.696 lbs. per square inch and a temperature at 212° F.

The latent heat of vaporization of water to steam is 970.3 Btu per lb. at atmospheric pressure.

The best designed boilers, well set, with good draft and skillful firing, will evaporate from 7 to 10 lbs. of water per pound of first-class coal.

With small boilers in industrial plants, heat liberations of approximately 15,000 Btu per cu. ft. of furnace volume per hour are attained, whereas, in large central stations, this can run up to 30,000 Btu per cu. ft. or higher.

The horsepower rating of a boiler is based on its heating surface, 10 square feet of heating surface being allowed per rated horsepower.

The relation between heat liberation, heating surface, per cent rating, and boiler efficiency is as follows:

$$\text{Heat liberation Btu per hr.} = \frac{\text{Heating Surface} \times 33{,}500 \times \%\ \text{Rating}}{10 \times \%\ \text{efficiency}}$$

The information on horsepower calculations, motors, steam and steam boilers is published through courtesy of "Compressed Air Data" and "Cameron Pump Data."

WATER HORSEPOWER FORMULAS

$$\text{Water H.P.} = \frac{\text{gal. per min.} \times \text{head in feet} \times \text{specific gravity}}{3960}$$

$$\text{or Water H.P.} = \frac{\text{gal. per min.} \times \text{head in lbs. per sq. in.}}{1714}$$

$$\text{Brake H.P.} = \frac{\text{Water H.P.}}{\text{Efficiency of Pump}}$$

$$\text{Kw. hrs. per 1,000 gal. cold water pumped per hour} = \frac{\text{head in feet of water} \times 0.00315}{\text{efficiency of pump} \times \text{efficiency of motor}}$$

Cameron Hydraulic Data.

EFFICIENCIES OF ELECTRIC MOTORS

Average Efficiencies for Voltages up to 550 in Three Phase Motors

Rating	Induction Motors			Unity P. F. Syn. Motors		
	Full Load	¾ Load	½ Load	Full Load	¾ Load	½ Load
1 to 2 Hp.	81	79	76			
3 to 5 Hp.	85	84	82			
10 to 25 Hp.	87.5	87	85			
25 to 50 Hp.	89	88.5	86.5	90	88.5	85
75 Hp.-100 Hp.	91	90	88	92	91	88
150-200 Hp.	92	91.5	89.5	93	92	89.5
Above 200 Hp.	93.5	93	91	94.5	93.5	92

The above are averages for 1200 and 1800 RPM motors.
Low speed motors.—Efficiencies will be from 1 to 2% lower—2200 volt motors 100 HP and above have approximately the same efficiency as low voltage motors. On smaller sizes the 2200 volt motors have efficiencies 1 to 2% lower.
Slip ring motors in the smaller sizes will have full load efficiencies of 1 to 3% lower.

POWER REQUIREMENTS OF POSITIVE BLOWERS AND EXHAUSTERS

$$\text{B.H.P.} = .00474 \times \text{D} \times \text{R.P.M.} \times \text{P.}$$

Where

B.H.P. equals horsepower required to drive the blower or exhauster.

D equals displacement in cubic feet per revolution.

R.P.M. equals revolutions per minute.

P equals outlet minus inlet pressure in pounds per square inch. (If inlet pressure is atmospheric, then P is the outlet gauge pressure.)

Note: This formula assumes a mechanical efficiency of 92 per cent for the blower or exhauster.

Volumetric efficiency is provided for since actual capacity is less than actual R.P.M. multiplied by displacement.

Engineering Tables—Roots-Connersville.

BEARING POWER OF SOILS

Bearing Power in Tons Per Square Foot

Minimum	Maximum	Type of Soil
200		Rock in thick layers—native.
25	30	Rock equal to best ashler masonry.
15	20	Rock equal to best brick masonry.
5	10	Rock equal to poor brick masonry.
4	6	Clay in thick beds always dry.
2	4	Clay in thick bed moderately dry.
1	2	Clay soft.
8	10	Gravel and coarse sand well cemented.
4	6	Sand compact and well cemented.
2	4	Sand clean and dry.
0.5	1	Quick sand and alluvial soils.

TABLE OF SUGGESTED CONCRETE MIXTURES

TYPE OF WORK	Gallons of Water Per Bag of Cement	Trial Mix
Structural parts, columns, etc., subjected to high stresses	5	1-1¾-2¾
Sea water concrete	4	1-1¾-2¾
Reinforced slabs	5	1-2-3
Concrete subjected to water pressure such as: Swimming pools, Reservoirs, Cisterns, Elevator pits, Vats, etc.	4½	1-2-3
Fence posts and other pre-cast units	5	1-2-3
Reinforced concrete such as: Walls, Columns, Girders, Beams	5½	1-2-3½
Retaining Walls	5	1-2-3½
Septic Tanks	5½	1-2-3½
Curbs, Driveways and Approaches	4½	1-2-3½
Engine foundations, heavily loaded and subjected to vibration	4½	1-2-3½
Sidewalks, Steps and Stairways	5½	1-2½-4
Silos, Grain and Coal Bins, and similar structures	5½	1-2½-4
Manure Pits, Dipping Vats, Hog Wallows	6	1-2½-4
Gutters, Runways, Hotbeds, etc.	5½	1-2½-4
Basement walls not subject to water pressure	6	1-2½-4
Footings, Foundations	6½	1-3 5
Heavy retaining walls	6	1-3-5
Engine foundations not subject to excessive vibration	6	1-3-5
Barnyard pavements and feeding floors	5½	1-3-5

Note:—Suggested water per bag of cement makes allowance for average moisture in aggregates as used. If the aggregates are wet the recommended water should be reduced 1 gallon per bag.

Do not adjust the water content to the mix. If the trial batch proves too stiff, reduce the amount of sand and stone until the desired consistency is obtained.

MATERIALS REQUIRED FOR 1 CUBIC YARD OF MORTAR AND CONCRETE

Mixture	¾" Gravel			1" Stone Dust Out			2½" Stone Dust Out			2½" Stone Most Small Stone Out		
	Barrels Cement	Cubic Yard Sand	Cubic Yard Stone	Barrels Cement	Cubic Yard Sand	Cubic Yard Stone	Barrels Cement	Cubic Yard Sand	Cubic Yard Stone	Barrels Cement	Cubic Yard Sand	Cubic Yard Stone
Mortar												
1:1½	3.61	0.80	Using	very	fine	sand	3.87	0.86		Using	coarse	sand
1:2	3.02	0.90	"	"	"	"	3.21	0.95		"	"	"
1:2½	2.60	0.96	"	"	"	"	2.74	1.01		"	"	"
1:3	2.28	1.01	"	"	"	"	2.39	1.06		"	"	"
Concrete												
1:1:2	2.30	0.35	0.74	2.57	0.39	0.78	2.63	0.40	0.80	2.72	0.41	0.83
1:1½:3	1.71	0.39	0.78	1.85	0.42	0.84	1.90	0.43	0.87	1.96	0.45	0.89
1:1¾:2¾	1.75	0.43	0.75	1.85	0.47	0.80	1.93	0.46	0.84	2.00	0.48	0.85
1:2:3	1.54	0.47	0.73	1.70	0.52	0.77	1.73	0.53	0.79	1.78	0.54	0.81
1:2:3½	1.44	0.44	0.77	1.57	0.48	0.83	1.61	0.49	0.85	1.66	0.50	0.88
1:2:4	1.34	0.41	0.81	1.46	0.44	0.89	1.48	0.45	0.90	1.53	0.47	0.93
1:2½:4	1.24	0.47	0.75	1.35	0.52	0.82	1.38	0.53	0.84	1.42	0.54	0.87
1:2½:4½	1.16	0.44	0.80	1.27	0.48	0.87	1.29	0.49	0.88	1.33	0.51	0.91
1:2½:5	1.10	0.42	0.83	1.19	0.46	0.91	1.21	0.46	0.92	1.26	0.48	0.96
1:3:4	1.15	0.52	0.72	1.26	0.58	0.77	1.28	0.58	0.78	1.32	0.60	0.80
1:3:5	1.03	0.47	0.78	1.11	0.51	0.85	1.14	0.52	0.87	1.17	0.54	0.89
1:3:6	0.92	0.42	0.84	1.01	0.46	0.92	1.02	0.47	0.93	1.06	0.48	0.97

WATER CEMENT RATIOS

Water cement ratio means the relation of water in volume to cement in volume as used to make concrete. For example, if the amount of water in the batch is 1 cubic foot (7½ gallons) and the amount of cement in the batch is also 1 cubic foot (1 sack) then the W/C ratio is 1.0. If the water content is 7 gallons per sack of cement, then the W/C will be $\frac{7}{7.5} = 0.933$ or 0.933 cu. feet of water per batch.

Water Cement Ratio by Volume	Gal. Water Per Sack of Cement	Lb. Water Per Sack of Cement	Lb. Water Per 10 lb. Cement
.53	4.0	33.2	3.53
.59	4.5	37.35	3.97
.66	5.0	41.5	4.41
.73	5.5	45.65	4.85
.80	6.0	49.8	5.29
.86	6.5	53.95	5.73
.93	7.0	58.1	6.17
1.00	7.5	62.5	6.61
1.06	8.0	66.4	7.05

94 lbs. cement = 1 sack
1 sack cement = 1 cu. ft.
7½ gals. water = 1 cu. ft.
62½ lbs. water = 1 cu. ft.
8⅓ lbs. water = 1 gallon

By "water" is meant water in the sand and stone plus that added at the mixer.

Very wet sand will contain from ¾ to 1 gallon per cubic foot.

Moderately wet sand will contain about ½ gallon per cubic foot.

Moist sand will contain about ¼ gallon per cubic foot.

NOTE: THE COARSER THE SAND, THE LESS WATER IT WILL CARRY.

Lehigh Portland Cement Co.

PHYSICAL CONSTANTS OF CHEMICAL ELEMENTS

Element	Symbol	Atomic Weight 1941	Specific Gravity 68° F.(1)	Melting Point °F.	Boiling Point °F.	Specific Heat at 68° F.	Coef. Linear Thermal Expansion per °F. at 65° F. ×10⁶(3)
Aluminum	Al	26.97	2.702	1218	3270	.214	12.8
Antimony	Sb	121.76	6.684	1165	2520	.050	6.3
Argon, gas	A	39.944	1.379	....	....	.125	....
liquid	A	39.944	1.42 (2)	—309	—302	.134 (5)	....
Arsenic, am.	As	74.91	3.70	....	....	.086 (6)	2.6
cryst.	As	74.91	5.727	(5)	1139	.082 (6)	2.6
Barium	Ba	137.36	3.5	1560	2080	.068	....
Beryllium	Be	9.02	1.85	2460	2787	.397	6.8 (5)
Bismuth	Bi	209.00	9.80	520	2640	.029	7.4
Boron	B	10.82	2.3	4200	4600	.309	....
Bromine, gas	Br	79.916	5.87 (2)	....	....	.055 (2)	....
liquid	Br	79.916	2.928	19	138	.107	....
Cadmium	Cd	112.41	8.642	610	1413	.055	16.6
Calcium	Ca	40.08	1.55	1490	2620	.155	14.0
Carbon, am.	C	12.010	1.90	6380	7600	.204	3.0
graphite	C	12.010	2.25	6380	7600	.168	4.4
diamond	C	12.010	3.52	6380	7600	.117	0.7
Cerium	Ce	140.13	6.91	1180	2550	.042 (6)	....
Cesium	Cs	132.91	1.90	83	1240	.052	54.0
Chlorine, gas	Cl	35.457	2.486	....	....	.115	....
liquid	Cl	35.457	1.557 (2)	—152	—29	.226 (2)	....
Chromium	Cr	52.01	6.92	2940	4000	.110	3.3 (4)
Cobalt	Co	58.94	8.71	2700	5250	.100	6.8
Columbium	Cb	92.91	8.4	3540	5250	...	4.0
Copper	Cu	63.57	8.92	1981	4190	.092	9.2
Dysprosium	Dy	162.46	....	....	....	...	....
Erbium	Er	167.2	4.77	....	....	...	....
Europium	Eu	152.0	....	....	....	...	....
Fluorine, gas	F	19.00	1.312	....	....	.182	....
liquid	F	19.00	1.108 (2)	—369	—305	...	....
Gadolinium	Gd	156.9	1.31	....	....	...	....
Gallium	Ga	69.72	5.903	86	3600	.079	10.0
Germanium	Ge	72.60	5.35	1757	4900	.074 (6)	9.3
Gold	Au	197.2	19.32	1945	4700	.031	7.9
Hafnium	Hf	178.6	13.3	4000	5800	...	....
Helium, gas	He	4.003	.138	—458	—452	1.25	....
Holmium	Ho	164.94	....	....	....	...	....
Hydrogen, gas	H	1.0080	.06952	....	....	3.391	....
liquid	H	1.0080	.071 (2)	—435	—423	.231 (2)	....
Indium	In	114.76	7.31	311	2640	.057 (6)	23.2
Iodine, gas	I	126.92	8.72 (2)	....	....	.034 (2)	....
solid	I	126.92	4.93	237	361	.052	52.0
Iridium	Ir	193.1	22.42	4420	8000	.031	3.6
Iron, pure	Fe	55.85	7.865	2795	5400	.107	6.5
wrought	Fe	55.85	7.78	2750	....	.111	6.8
gray steel	Fe	55.85	7.86	2680	....	.115	6.9
cast	Fe	55.85	7.1	2245	....	.115	5.8
Krypton, gas	Kr	83.7	2.868	....	....	...	....
liquid	Kr	83.7	2.16 (2)	—251	—243	...	....
Lanthanum	La	138.92	6.15	1519	3300	.045 (6)	....
Lead	Pb	207.21	11.344	621	2935	.031	15.9
Lithium	Li	6.940	.534	367	2437	.830	31.0
Lutecium	Lu	174.99	....	....	....	...	....
Magnesium	Mg	24.32	1.74	1204	2030	.246	14.0
Manganese	Mn	54.93	7.20	2300	3450	.121 (5)	13.0
Mercury, liquid	Hg	200.61	13.546	—38	674	.03325	101.0 (7)
Molybdenum	Mo	95.95	10.2	4750	6700	.065 (5)	2.7 (8)
Neodymium	Nd	144.27	6.9	1540	....	.045 (6)	....
Neon, gas	Ne	20.183	.696	—416	—411	...	....
Nickel	Ni	58.69	8.90	2646	5250	.105	7.1
Nitrogen, gas	N	14.008	.9673	....	....	.2477	....
liquid	N	14.008	.808 (5)	—346	—320	.474 (5)	....
Osmium	Os	190.2	22.48	4900	>9550	.031 (5)	3.4
Oxygen, gas	O	16.0000	1.1053	....	....	.2178	....
liquid	O	16.0000	1.14 (2)	—361	—297	.394 (2)	....
Ozone, gas	O_3	....	1.658	—420	—170	...	....
Palladium	Pd	106.7	11.97	2830	>4000	.055	6.5
Phosphorus, yellow	P	30.98	1.82	111	....	.189	69.0
red	P	30.98	2.20	1094 at 43 atm.	....	.190	....
liquid	P	30.98	1.745 (5)	....	536	...	....
Platinum	Pt	195.23	21.45	3224	7770	.032	5.0
Potassium	K	39.096	.86	144	1400	.184	46.0
Praseodymium	Pr	140.92	6.5	1725	....	.046 (6)	....
Protactinium	Pa	231	....	5430	....	...	....
Radium	Ra	226.05	5.0	1760	2080	...	....
Radon, gas	Rn	222	7.526	....	....	...	....
solid	Rn	222	4.0 (5)	—96	—79	...	....
Rhenium	Re	186.31	20.53	6220	....	.033	....
Rhodium	Rh	102.91	12.5	3600	>4500	.059	4.7
Rubidium	Rb	85.48	1.532	101	1290	.080	48.0
Ruthenium	Ru	101.7	12.063	4440	7500	.061 (6)	5.1
Samarium	Sm	150.43	7.7	>2370	....	...	....
Scandium	Sc	45.10	2.5	2200	4350	...	....
Selenium, gray	Se	78.96	4.79	423	1270	.077	20.4
red	Se	78.96	4.46	....	1270	...	....
Silicon	Si	28.06	2.4	2590	4700	.173	4.1
Silver	Ag	107.880	10.5	1761	3540	.056	10.5
Sodium	Na	22.997	.971	208	1616	.295	39.0
Strontium	Sr	87.63	2.6	1386	2100	.074	....
Sulphur, rhombic	S	32.06	2.07	235	832	.173	36.0
monoclinic	S	32.06	1.96	246	832	.181	36.0
amorphous	S	32.06	1.92	>250	832	...	36.0
Tantalum	Ta	180.88	16.6	5160	>7400	.036	3.7
Tellurium, amorphous	Te	127.61	6.00	846	2535	.053	9.3
cryst.	Te	127.61	6.25	846	2535	.048	9.3
Terbium	Tb	159.2	....	621	....	.048	....
Thallium	Tl	204.39	11.85	578	3000	.031	16.8
Thorium	Th	232.12	11.2	3350	>5400	.028 (6)	6.2 (4)
Thulium	Tm	169.4	....	....	....	....	....
Tin, gray	Sn	118.70	5.75	449	4120	.052	....
rhombic	Sn	118.70	6.53	449	4120	...	....
tetrahedral	Sn	118.70	7.28	449	4120	.054	13.7
Titanium	Ti	47.90	4.5	3270	>5400	.100	....
Tungsten	W	183.92	19.3	6100	10650	.031	2.4
Uranium	U	238.07	18.7	>3360	....	.028 (6)	....
Vanadium	V	50.95	5.866	3120	5430	.115 (6)	....
Xenon, gas	Xe	131.3	4.525	....	....	...	....
liquid	Xe	131.3	3.06 (2)	—170	—161	...	....
Ytterbium	Yb	173.04	....	3270	....	...	....
Yttrium	Y	88.92	5.51	2700	4530	...	....
Zinc	Zn	65.38	7.14	787	1665	.092	16.5
Zirconium	Zr	91.22	6.4	3450	>5250	.066	....

(1) Specific Gravity.—the density of the element at 68° F. (20° C.) has been compared to that of water at 60° F. in the case of liquids and solids (unless otherwise noted). The density of gases has been compared to that of air.

(2) At boiling point.

(3) 10^6 means that for convenience the coefficients of linear expansion have been multiplied by 1,000,000 to obtain the figures shown in the table. In using move the decimal point 6 places to the left. Thus the coefficient of linear thermal expansion for Aluminum is .0000128.

(4) 68° to 140° F.

(5) Sublimes.

(6) 32° to 212° F.

(7) Cubical expansion coefficient.

(8) At melting point.

(9) 68° to 212° F.

WEIGHTS AND SPECIFIC GRAVITIES

Substance	Weight Lb. per Cu. Ft.	Specific Gravity
METALS, ALLOYS, ORES		
Aluminum, cast, hammered	165	2.55-2.75
Aluminum, bronze	481	7.7
Brass, cast, rolled	534	8.4-8.7
Bronze, 7.9 to 14% Sn	509	7.4-8.9
Copper, cast, rolled	556	8.8-9.0
Copper ore, pyrites	262	4.1-4.3
Gold, cast, hammered	1205	19.25-19.3
Iron, cast, pig	450	7.2
Iron, wrought	485	7.6-7.9
Iron, steel	490	7.8-7.9
Iron ore, hematite	325	5.2
Iron ore, hematite loose	130-160	.....
Lead	710	11.37
Mercury	849	13.6
Nickel	565	8.9-9.2
Nickel, monel metal	556	8.8-9.0
Platinum, cast, hammered	1330	21.1-21.5
Silver, cast, hammered	656	10.4-10.6
Tin, cast, hammered	459	7.2-7.5
Zinc, cast, rolled	440	6.9-7.2
VARIOUS SOLIDS		
Hay and straw.....bales	20	.....
Cotton, Flax, Hemp	93	1.47-1.50
Glass, common	156	2.40-2.60
Leather	59	0.86-1.02
Paper	58	0.70-1.15
Rubber goods	94	1.0-2.0
Salt, granulated, piled	48	.....
Saltpeter	67	.....
Sulphur	125	1.93-2.07
Wool	82	1.32
TIMBER, U. S. SEASONED		
Moisture Content by Weight: Seasoned timber 15 to 20% Green timber up to 50%		
Ash, white, red	40	0.62-0.65
Cedar, white, red	22	0.32-0.38
Cypress	30	0.48
Fir, Douglas spruce	32	0.51
Fir, eastern	25	0.40
Elm, white	45	0.72
Hemlock	29	0.42-0.52
Hickory	49	0.74-0.84
Maple, hard	43	0.68
Maple, white	33	0.53
Oak, chestnut	54	0.86
Oak, live	59	0.95
Oak, red, black	41	0.65
Oak, white	46	0.74
Pine, Oregon	32	0.51
Pine, red	30	0.48
Pine, white	26	0.41
Pine, yellow, long-leaf	44	0.70
Pine, yellow, short-leaf	38	0.61
Poplar	30	0.48
Redwood, California	26	0.42
Spruce, white, black	27	0.40-0.46
Walnut, black	38	0.61
Walnut, white	26	0.41
VARIOUS LIQUIDS		
Alcohol, 100%	49	0.79
Acids, muriatic 40%	75	1.20
Acids, nitric 91%	94	1.50
Acids, sulphuric 87%	112	1.80
Lye, soda 66%	106	1.70
Oils, vegetable	58	0.91-0.94
Oils, mineral, lubricants	57	0.90-0.93
Water, ice	56	0.88-0.92
Water, snow, fresh fallen	8	.125
Water, sea water	64	1.02-1.03
REFRACTORIES		
Brick, fire clay	125-140	2.0-2.2
Brick, silica	100-112	1.6-1.8
Brick, chrome	180-190	2.9-3.1
Brick, magnesite	162-175	2.6-2.8
Chrome cement	135-145	.....
Fire clay	80-85	.....
Magnesite cement	130-140	.....
Silica cement	75-80	.....

Substance	Weight Lb. per Cu. Ft.	Specific Gravity
BRICK MASONRY		
Granite, syenite, gneiss	140	2.2-2.3
Common brick	120	1.8-2.0
Soft brick	100	1.5-1.7
CONCRETE MASONRY		
Cement, stone, sand	144	2.2-2.4
Cement, slag, etc	130	1.9-2.3
Cement, cinder, etc	100	1.5-1.7
VARIOUS BUILDING MATERIALS		
Ashes, cinders	40-45	.....
Cement, portland, loose	94	.....
Cement, portland, set	183	2.7-3.2
Lime, gypsum, loose	53-64	.....
Mortar, set	103	1.4-1.9
Slags, bank slag	67-72	.....
Slags, bank screenings	98-117	.....
Slags, machine slag	96	.....
Slags, slag sand	49-55	.....
EARTH, ETC., EXCAVATED		
Clay, dry	63	.....
Clay, damp, plastic	110	.....
Clay and gravel, dry	100	.....
Earth, dry, loose	76	.....
Earth, dry, packed	95	.....
Earth, moist, loose	78	.....
Earth, moist, packed	96	.....
Earth, mud, flowing	108	.....
Earth, mud, packed	115	.....
Riprap, limestone	80-85	.....
Riprap, sandstone	90	.....
Riprap, shale	105	.....
Sand, gravel, dry, loose	90-105	.....
Sand, gravel, dry, packed	100-120	.....
Sand, gravel dry, wet	118-120	.....
EXCAVATIONS IN WATER		
Sand or gravel	60	.....
Sand or gravel and clay	65	.....
Clay	80	.....
River mud	90	.....
Soil	70	.....
Stone riprap	65	.....
MINERALS		
Asbestos	153	2.1-2.8
Chalk	137	1.8-2.6
Clay, marl	137	1.8-2.6
Granite, syenite	175	2.5-3.1
Greenstone, trap	187	2.8-3.2
Gypsum, alabaster	159	2.3-2.8
Limestone, marble	165	2.5-2.8
Phosphate rock, apatite	200	3.2
Pumice, natural	40	0.37-0.90
Quartz, flint	165	2.5-2.8
Sandstone, bluestone	147	2.2-2.5
Shale, slate	175	2.7-2.9
Soapstone, talc	169	2.6-2.8
COAL AND COKE, PILED		
Coal, anthracite	47-58	.....
Coal, bituminous, lignite	40-54	.....
Peat, turf	20-26	.....
Charcoal	10-14	.....
Coke	23-32	.....
BITUMINOUS SUBSTANCES		
Asphaltum	81	1.1-1.5
Coal, anthracite	97	1.4-1.7
Coal, bituminous	84	1.2-1.5
Lignite	78	1.1-1.4
Peat, turf, dry	47	0.65-0.85
Charcoal, pine	23	0.28-0.44
Charcoal, oak	33	0.47-0.57
Coke	75	1.0-1.4
Graphite	131	1.9-2.3
Paraffine	56	0.87-0.91

The specific gravities of solids and liquids refer to water at 4°C., those of gases to air at 0°C. and 760 mm. pressure. The weights per cubic foot are derived from average specific gravities, except where stated that weights are for bulk, heaped or loose material, etc.

GAS COMBUSTION CONSTANTS

No.	Gas	Formula	Molecular Wt.	Lbs. per Cu. Ft.	Cu. Ft. per Lb.	Sp. Gr. Air = 1.000	Heat of Combustion: B.t.u. per Cu. Ft. Gross	Heat of Combustion: B.t.u. per Cu. Ft. Net	Heat of Combustion: B.t.u. per Lb. Gross	Heat of Combustion: B.t.u. per Lb. Net	Cu. Ft. per Cu. Ft. of Combustible: Required for Combustion: O_2	N_2	Air	Cu. Ft. per Cu. Ft. of Combustible: Flue Products: CO_2	H_2O	N_2	Lbs. per Lb. of Combustible: Required for Combustion: O_2	N_2	Air	Lbs. per Lb. of Combustible: Flue Products: CO_2	H_2O	N_2
1	Carbon	C	12.000						14,140†	14,140†							2.667	8.873	11.540	3.667		8.873
2	Hydrogen	H_2	2.015	0.005327	187.723	0.06950	323.5	275.1	61,100	51,643	0.5	1.882	2.382		1.0	1.882	7.939	26.414	34.353		8.939	26.414
3	Oxygen	O_2	32.000	0.08461	11.819	1.1053																
4	Nitrogen (atmos.)	N_2	28.016	0.07439*	13.443*	0.9718*																
5	Carbon monoxide	CO	28.000	0.07404	13.506	0.9672	323.5**	323.5	4,369	4,369	0.5	1.882	2.382	1.0		1.882	0.571	1.900	2.471	1.571		1.900
6	Carbon dioxide	CO_2	44.000	0.1170	8.548	1.5282																
Paraffin Series C_nH_{2n+2}																						
7	Methane	CH_4	16.031	0.04243	23.565	0.5543	1014.7‡	913.8	23,912	21,533	2.0	7.528	9.528	1.0	2.0	7.528	3.992	13.282	17.274	2.745	2.248	13.282
8	Ethane	C_2H_6	30.046	0.08029*	12.455*	1.04882*	1781	1631	22,215	20,312	3.5	13.175	16.675	2.0	3.0	13.175	3.728	12.404	16.132	2.929	1.799	12.404
9	Propane	C_3H_8	44.062	0.1196*	8.365*	1.5617*	2572	2371	21,564	19,834	5.0	18.821	23.821	3.0	4.0	18.821	3.631	12.081	15.712	2.996	1.635	12.081
10	Iso-Butane	C_4H_{10}	58.077	0.1582*	6.321*	2.00654*	3251	2999	21,247	19,606	6.5	24.467	30.967	4.0	5.0	24.467	3.581	11.914	15.495	3.030	1.551	11.914
11	n-Butane	C_4H_{10}	58.077	0.1582*	6.321*	2.00654*	3353	3102	21,247	19,606	6.5	24.467	30.967	4.0	5.0	24.467	3.581	11.914	15.495	3.030	1.551	11.914
12	n-Pentane	C_5H_{12}	72.092	0.1904*	5.252*	2.4872*	3981	3679	20,908	19,322	8.0	30.114	38.114	5.0	6.0	30.114	3.551	11.815	15.366	3.052	1.499	11.815
13	n-Hexane	C_6H_{14}	86.107	0.2274*	4.398*	2.9704*	4667	4315	20,526	18,976	9.5	35.760	45.260	6.0	7.0	35.760	3.530	11.745	15.275	3.067	1.465	11.745
Olefin Series C_nH_{2n}																						
14	Ethylene	C_2H_4	28.031	0.07456	13.412	0.9740	1631	1530	21,884	20,525	3.0	11.293	14.293	2.0	2.0	11.293	3.425	11.395	14.820	3.139	1.285	11.395
15	Propylene	C_3H_6	42.046	0.1110*	9.007*	1.4504*	2336	2185	21,042	19,683	4.5	16.939	21.439	3.0	3.0	16.939	3.425	11.395	14.820	3.139	1.285	11.395
16	Butylene	C_4H_8	56.062	0.1480*	6.756*	1.9336*	3135	2884	20,840	19,481	6.0	22.585	28.585	4.0	4.0	22.585	3.425	11.395	14.820	3.139	1.285	11.395
17	Acetylene	C_2H_2	26.015	0.06971	14.344	0.9107	1503	1453	21,572	20,840	2.5	9.411	11.911	2.0	1.0	9.411	3.075	10.231	13.306	3.383	0.692	10.231
Aromatic Series C_nH_{2n-6}																						
18	Benzene	C_6H_6	78.046	0.2060*	4.852*	2.6920*	3741	3590	18,150	17,418	7.5	28.232	35.732	6.0	3.0	28.232	3.075	10.231	13.306	3.383	0.692	10.231
19	Toluene	C_7H_8	92.062	0.2431*	4.113*	3.1760*	4408	4206	18,129	17,301	9.0	33.878	42.878	7.0	4.0	33.878	3.128	10.407	13.535	3.346	0.783	10.407
20	Xylene	C_8H_{10}	106.077				5155		18,410		10.5	39.524	50.024	8.0	5.0	39.524	3.168	10.540	13.708	3.318	0.849	10.540
21	Naphthalene	$C_{10}H_8$	128.062				5859		17,298		12.0	45.170	57.170	10.0	4.0	45.170	2.999	9.978	12.977	3.436	0.563	9.978
Miscellaneous Gases																						
22	Ammonia	NH_3	17.031	0.04563*	21.914*	0.5961	433		9,598													
23	Hydrogen sulfide	H_2S	34.080	0.09109*	10.979*	1.1898*	672		7,479		1.5	5.646	7.146	SO_2 = 1.0	1.0	5.646	1.408	4.685	6.093	SO_2 = 1.880	0.529	4.685
24	Sulfur dioxide	SO_2	64.06	0.1733	5.770	2.264																
25	Water vapor	H_2O	18.015	0.04758*	21.017*	0.6215*																
26	Air		28.9	0.07655	13.063	1.0000																

NOTES:

All gas volumes corrected to 60° F. and 30″ Hg dry.

Molecular weights calculated from atomic weights given in the International Critical Tables.

* Densities calculated from values given in grams per liter at 0° C. and 760 mm. in the International Critical Tables allowing for the known deviations from the gas laws. Where the coefficient of expansion was not available, the assumed value was taken as 0.0037 per ° C. Compare this with 0.003662 which is the coefficient for a perfect gas. Where no densities were available the volume of the mol was taken as 22.4115 liters. The asterisk (*) denotes that either the density or the coefficient of expansion has been assumed.

Some of the materials cannot exist as gases at 60° F. and 30″ Hg pressure, in which case the values are theoretical ones given for ease of calculation of gas problems. Under the actual concentrations in which these materials are present their partial pressure is low enough to keep them as gases.

The heats of combustion have been obtained by reviewing the experimental and critical data available. The 1929 A.G.A. Chemical Committee examined and approved the selection for the Gas Chemists Handbook. As far as possible the net heat of combustion per lb. is the base figure from which all others were calculated. The data, given in mean B.t.u. per lb. ($^1/_{100}$th of the heat per lb. of water from 32° F. to 212° F.) have been compiled largely from Bureau of Standards publications, Bulletins of the Univ. of Illinois Engineering Exp. Station, International Critical Tables, etc.

† Carbon—Roth and Naesser, Z. für Elektrochemie 31:461 (1925). White and black diamonds.

‡ Methane—Research Paper 260, Bureau of Standards (Jan. 1931) corrected. C_3H_{10}, $C_{10}H_8$, H_2S and NH_3 from 1929 A.G.A. Gas Chemists Handbook.

For precise calculations with gases saturated with water vapor, 1.73% of the B.t.u. value must be deducted to correct for the presence of water vapor.

Gross heating values are calculated from the net by allowing for the heat of vaporization of water at 60° F., amounting to 50.3 B.t.u. per cu. ft. of water vapor or 1057.8 B.t.u. per lb.

** Rossini in Bureau of Standards Research Paper 260 finds the heat of combustion of carbon monoxide to be 321.7 B.t.u. per cu. ft. Although not adopted for this edition, there is reason to believe that Rossini's value is the most accurate now available.

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Heats of Combustion at 60° F, and Flame Temperatures for Carbon, Hydrogen, and Some of Their Components

Carbon as Graphite

Reaction	Heat of combustion at 60°F			Max. flame temp., °F; corrected for dissociation (burned with theoret. air)
	Gross	Net	Btu per lb or cu ft	
$C + \frac{1}{2}O_2 \rightarrow CO$	3,964.	3,964.	lb	
$C + O_2 \rightarrow CO_2$	14,155.	14,155.	lb	3,820
$CO + \frac{1}{2}O_2 \rightarrow CO_2$	323.4	323.4	cu ft	3,960
$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$	325.1	274.8	cu ft	3,960
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	1,010.7	909.8	cu ft	3,640
$C_2H_6 + 3\frac{1}{2}O_2 \rightarrow 2CO_2 + 3H_2O$	1,783.3	1,630.4	cu ft	3,710
$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$	2,572.	2,365.	cu ft	3,770
C_4H_{10}(iso) $+ 6\frac{1}{2}O_2 \rightarrow 4CO_2 + 5H_2O$	3,353.	3,093.	cu ft	3,780
C_5H_{12}(n) $+ 8O_2 \rightarrow 5CO_2 + 6H_2O$	3,987.	3,685.	cu ft	3,720
$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$	1,606.1	1,504.6	cu ft	3,910
$C_3H_6 + 4\frac{1}{2}O_2 \rightarrow 3CO_2 + 3H_2O$	2,332.	2,181.	cu ft	3,830
C_4H_8(iso) $+ 6O_2 \rightarrow 4CO_2 + 4H_2O$	3,077.	2,876.	cu ft	3,810
$C_2H_2 + 2\frac{1}{2}O_2 \rightarrow 2CO_2 + H_2O$	1,498.3	1,447.4	cu ft	4,250
$C_6H_6 + 7\frac{1}{2}O_2 \rightarrow 6CO_2 + 3H_2O$	3,744.	3,593.	cu ft	3,860
	*l*17,980.	17,250.	lb	3,840
$C_7H_8 + 9O_2 \rightarrow 7CO_2 + 4H_2O$	*l*18,300.	17,470.	lb	3,850
$C_{10}H_8 + 12O_2 \rightarrow 10CO_2 + 4H_2O$	*s*17,290.	16,690.	lb	

The cubic foot is measured at 60°F and 30 in. Hg.
Densities of C_2H_6, C_4H_{10}, C_5H_{12}, and C_6H_6 computed from the gas laws.
All gases are dry.
l = liquid, *s* = solid.

[1] Computed from I.C.T. values.

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PROPERTIES OF AIR AT ELEVATED TEMPERATURES

Temperature degrees F	Gas gravity	Density in lb per cu ft	Volume of 1 cu ft 60° air (or gas)	Volume of 1 lb dry air in cu ft	Heat content of dry air			% Volume of water vapor in saturated air	Viscosity lb/sec ft	Thermal Conductivity Btu ft / hr sq ft °F
					Btu/lb	Btu/cu ft of heated air	Btu/cu ft of 60° air			
60	1.000	0.0763	1.00	13.1	0	0	0	1.74	0.0000119	0.0136
80	0.962	0.0734	1.04	13.6	4.73	0.347	.361	3.45	0.0000125	0.0140
100	0.928	0.0708	1.08	14.1	9.46	0.670	.722	6.46	0.0000128	0.0145
120	0.897	0.0684	1.12	14.6	14.4	0.985	1.10	11.6	0.0000131	0.0149
140	0.867	0.0662	1.15	15.1	19.2	1.27	1.46	19.7	0.0000133	0.0153
160	0.839	0.0640	1.19	15.6	24.0	1.54	1.83	32.3	0.0000139	0.0158
180	0.812	0.0620	1.23	16.1	28.8	1.79	2.20	51.1	0.0000142	0.0162
200	0.787	0.0602	1.27	16.6	33.6	2.02	2.56	78.5	0.0000144	0.0166
250	0.733	0.0559	1.36	17.9	45.7	2.56	3.49	....	0.0000153	0.0174
300	0.684	0.0522	1.46	19.1	57.7	3.01	4.40	....	0.0000161	0.0182
400	0.604	0.0461	1.66	21.7	81.8	3.77	6.24	....	0.0000175	0.0200
500	0.541	0.0413	1.85	24.2	106	4.38	8.09	....	0.0000186	0.0214
600	0.493	0.0375	2.03	26.7	130	4.88	9.92	....	0.0000200	0.0229
700	0.450	0.0343	2.22	29.2	155	5.32	11.8	....	0.0000211	0.0243
800	0.415	0.0316	2.41	31.6	179	5.66	13.7	....	0.0000222	0.0257
900	0.383	0.0292	2.61	34.2	203	5.93	15.5	....	0.0000236	0.0270
1000	0.356	0.0272	2.81	36.8	235	6.39	17.9	....	0.0000247	0.0283
1200	0.313	0.0239	3.19	41.8	289	6.91	22.1	....	0.0000270	0.0308
1400	0.280	0.0214	3.57	46.8	343	7.32	26.2	....	0.0000292	0.0328
1600	0.253	0.0193	3.95	51.8	398	7.68	30.4	....	0.0000311	0.0346
1800	0.230	0.0176	4.34	56.9	455	8.00	34.7	....	0.0000333	0.0360
2000	0.211	0.0161	4.73	62.0	509	8.21	38.8	....	0.0000353	0.0370
2500	0.176	0.0134	5.68	74.5	....	....	....	....	.....	....
3000	0.151	0.0115	6.64	87.1	....	....	....	....	.....	....

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to believe that Rossini's value is the most accurate now available.
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COMBUSTION CHARACTERISTICS OF TYPICAL GASES

(CALCULATED ON DRY BASIS)

Kind of Gas	Constituents of Gas—Per Cent by Volume										Specific Gravity	B.t.u. per Cu. Ft.		Cu. Ft. of Air per Cu. Ft. of Gas	Products of Combustion per Volume of Gas			Ultimate % CO_2
	CO_2	O_2	N_2	CO	H_2	Ill.	CH_4	C_2H_6	C_3H_8	C_4H_{10}		Gross	Net		CO_2	H_2O Vapor	N_2	
Natural Gas, Kettleman Hills, California—Stripped Casinghead	...	...	...	...	...	...	85.4	8.6	5.1	0.9	.67	1183	1071	11.06	1.215	2.215	8.742	12.2
Natural Gas, Long Beach, Los Angeles Basin, California — Stripped Casinghead	0.5	.	...	..	...	..	86.8	7.2	4.3	1.2	.66	1161	1051	10.87	1.194	2.184	8.587	12.2
Natural Gas, San Joaquin Valley, California—Dry	0.1	...	1.2	..	...	...	98.7	..	..	...	.56	1000	902	9.40	.987	1.974	7.442	11.7
Natural Gas, Gulf Coast Area, Texas—Stripped	0.2	1.0	7.7	..	.	. .	88.8	2.3	...	...	.61	941	849	8.80	.934	1.845	7.027	11.7
Natural Gas—Texas Panhandle	0.1	0.1	7.7	..	...	...	82.2	6.1	2.4	1.4	.67	1052	952	9.85	1.076	1.997	7.882	12.0
Natural Gas, West Virginia	0.8	...	1.1	..	...	...	75.0	23.1	...	...	.69	1174	1064	11.00	1.212	2.193	8.700	12.2
Natural Gas—Casinghead, Unstripped	1.0	..	1.1	..	...	...	66.6	31.3	...	...	.74	1236	1122	11.56	1.292	2.271	9.148	12.4
Natural Gas—Sour	...	..	...	H_2S	6.4	..	58.7	16.5	9.9	8.5	.91	1478	1348	13.79	1.589 SO_2 .064	2.589	11.094	12.5
Coal Gas (Horizontal Retort)	2.1	0.4	3.5	8.7	50.5	3.8	28.2	2.8	..	...	.43	612	549	5.28	.568	1.240	4.241	11.8
Coal Gas (Horizontal Retort)	2.8	0.6	8.8	7.4	41.6	4.5	34.3	...	...	...	.49	606	545	5.27	.589	1.206	4.299	12.1
Coal Gas (Vertical Retort)	3.0	0.6	3.1	7.0	50.4	3.1	32.8	..	...	...	.41	587	525	5.06	.527	1.231	4.060	11.5
By-Product Coke Oven Gas	2.1	0.4	6.1	5.0	52.9	3.2	30.3	...	...	...	.40	565	505	4.86	.476	1.209	3.935	10.8
By-Product Coke Oven Gas	1.5	0.3	5.0	5.0	58.0	2.8	27.4	...	...	...	.36	544	484	4.64	.429	1.192	3.741	10.3
By-Product Coke Oven Gas	2.5	0.8	10.1	11.1	47.6	3.4	24.5	...	...	...	.47	513	461	4.35	.490	1.044	3.571	12.1
By-Product Coke Oven Gas	2.3	1.5	12.0	7.8	46.8	4.0	24.6	1.0	...	...	.48	532	478	4.51	.495	1.082	3.723	11.7
Carburetted Water Gas—Gas Oil Enrichment	3.3	0.7	3.8	33.4	38.1	10.7	10.0	...	...	...	.65	563	520	4.53	.799	.827	3.822	17.3
Carburetted Water Gas—Heavy Oil with Blow-Run	4.6	0.6	16.7	24.1	32.5	10.3	9.0	2.2	...	...	.71	535	494	4.38	.740	.808	3.825	16.2
Carburetted Water Gas—Heavy Oil with Blow-Run	5.8	0.6	11.5	25.0	34.4	9.2	13.5	...	...	...	.68	527	485	4.32	.737	.826	3.717	16.5
Carburetted Water Gas—Heavy Oil with Reforming and Blow Run	5.3	0.6	12.8	21.9	36.5	8.3	14.6	...	...	...	.65	515	472	4.24	.684	.848	3.648	15.8
Carburetted Water Gas—High Heating Value	1.1	0.6	3.8	13.7	30.5	15.8	33.1	1.4	...	...	.63	820	753	7.23	.986	1.404	5.754	14.6
Uncarburetted Water Gas	6.2	0.3	3.0	39.2	49.0	...	2.3		...	...	.55	309	281	2.31	.477	.536	1.852	20.5
Butane Air Gas	. .	17.6	65.4	...	...	...	...	...	...	16.0	1.17	544	503	4.11	.640	.800	3.915	14.1
Propane Air Gas	...	16.6	62.4		.	...	...	...	21.0	...	1.12	544	501	4.21	.630	.840	3.952	13.7
Propane Air Gas	...	14.5	54.6	..	. .	..	...	...	30.9	...	1.17	801	737	6.67	.927	.1236	5.815	13.7
Refinery Oil Gas—Liquid Phase Cracking (Cross Still)	...	0.2	0.6	1.2	6.1	15.0	4.4	72.5	...	...	1.00	1665	1530	15.35	1.926	2.654	12.208	13.6
Refinery Oil Gas—Vapor Phase Cracking (Gyro Still)	0.1	1.0	...	1.2	13.1	39.6	23.3	21.7	...	...	.88	1465	1350	13.20	1.789	2.119	10.626	14.4
Reformed Refinery Oil Gas	4.0	0.6	4.8	18.2	52.1	3.6	16.7	...	...	...	.47	476	429	3.93	.504	.938	3.189	13.6
Reformed Natural Gas—Water Gas Generator	1.9	0.2	5.5	17.1	39.1	2.3	32.9	...	...	...	.50	566	511	4.91	.593	1.102	3.964	13.0
Oil Gas	3.0	0.6	4.4	9.7	50.2	4.0	28.1	...	...	...	.44	567	509	4.85	.536	1.156	3.912	12.1
Producer Gas—Anthracite	6.6	...	49.0	25.1	18.7	0.3	0.3	...	...	...	.84	151	141	1.13	.330	.200	1.386	19.2
Producer Gas — Bituminous	2.5	0.3	55.3	27.0	12.0	0.4	2.5	...	...	...	.87	160	151	1.23	.333	.179	1.529	17.9
Blast Furnace Gas	9.4	...	61.8	27.8	1.0	...	...	...	...	...	1.01	93	92	.69	.372	.010	1.160	24.3

CHARACTERISTICS OF SIMPLE GASES

Simple Gases and Compounds	Critical Temperature ° F.	Critical Pressure, Lbs. per Sq. In. Absolute	Limits of Inflammability Lower % by Volume Gas in Air	Limits of Inflammability Upper % by Volume Gas in Air	Ignition Temperature	Combustion Velocity of Maximum Speed Mixture in Feet per Second	Toxicity: Maximum Amt. Inhaled for One Hour without Serious Disturbance, P.P.M.	Toxicity: Dangerous in 30 Minutes to One Hour, P.P.M.	Toxicity: Rapidly Fatal, P.P.M.	Solubility in Lbs. per Lb. Water 60° F 30" Hg	Thermal Conductivity, B.t.u. per S.F. per ° F. per In. per Sec.	Specific Gravity of the Liquid 60/60° F.	Heat of Vaporization at 60° F. B.t.u. per Lb.
H_2	−400	188	4.1	74	1076–1094	8.2*	Simple asphyxiant			0.0$_4$167	0.0$_3$305	..	...
O_2	−181	731	..	...	.....	..	.....	.....	....	0.0$_4$49	0.0$_4$447	..	...
N_2	−233	492	..	...	.....	..	Simple asphyxiant			0.0$_4$22	0.0$_4$438	..	...
CO	−218	515	12.5	74	1191–1216	1.6*	1000–1200	1500–2000	4,000	Very slight	0.0$_4$412	..	...
CO_2	88	1,073	..	...	.....	..	5 to 7% respiratory stimulant			0.0019	0.0$_4$263	..	...
CH_4	−116	673	5.3	14.0	1200–1382	1.2*	.... Simple asphyxiant			.....	0.0$_4$564	..	223
C_2H_6	90	717	3.2	12.5	968–1166	..	Simple asphyxiant			.....	0.0$_4$346	0.38	210
C_3H_8	204	632	2.4	9.5	965 approx.	..	Anesthetic			.....	.....	0.51	183
n-C_4H_{10}	308	529	1.9	8.5	930 approx.	1.03	Anesthetic			.....	.....	0.58	166
iso-C_4H_{10}	273	544	..	...	.....	..	.....	.....	....	.....	.....	0.56	159
n-C_5H_{12}	387	485	1.4	8.0	890 approx.	..	Anesthetic, convulsive, irritant			.....	0.0$_4$223	0.63	153
iso-C_5H_{12}	370	482	..	...	.....	..	Anesthetic, convulsive, irritant			.....	.....	..	...
C_6H_{14}	455	434	..	...	.....	..	Anesthetic, convulsive, irritant			.....	0.0$_4$198	0.66	143
C_2H_2	49	748	3.3	34**	1000–1020	2.1*	Simple asphyxiant and anesthetic			.....	0.0$_4$314	..	...
C_3H_6	198	662	2.2	10	.....	..	Anesthetic			.....	.....	..	...
C_4H_8	...	...	1.7	9	.....	..	Anesthetic			.....	.....	..	...
C_2H_2	97	911	2.5	80	763–824	4.1*	Simple asphyxiant and anesthetic			.....	0.0$_4$332	..	...
C_6H_6	551	701	1.4	8.0	1364	..	3100–4700	.....	19,000	.....	0.0$_4$160	0.88	...
C_7H_8	609	612	1.3	6.75	1490	..	3100–4700	.....	19,000	.....	.....	..	...
C_8H_{10}	...	...	..	...	.....	..	3100–4700	.....	19,000	.....	.....	..	...
$C_{10}H_8$	...	...	..	...	.....	..	.....	.....	....	.....	.....	..	...
NH_3	270	1,639	16	27	.....	..	300–500	.....	5,000 10,000	0.612	0.0$_3$384	..	...
H_2S	212	1,307	..	...	.....	..	200–300	500–700	1,000 3,000	0.00466	0.0$_4$230	..	...
H_2O	706	3,226	..	...	.....	..	.....	.....	....	.....	0.0$_4$417	..	1058
Air	−285	547	..	...	.....	..	.....	.....	....	.....	0.0$_4$428	..	...

* Passauer. Das Gas und Wasserfach 73:313. Apr. 1930.
** Maximum reported in Bulletin 279, Bureau of Mines.

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AVERAGE FLUE GAS DEW POINT FOR VARIOUS FUELS*

Fuel	*Average dew point (Temperature, °F)*
Anthracite	68
Semi-bituminous coal	84
Bituminous coal	93
Oil	111
Natural gas	127
Manufactured gas	137
Propane gas (2,500 Btu/cu ft)	119
Butane gas (3,200 Btu/cu ft)	124
Butane-air gas mixture (535 Btu/cu ft)	121

* American Society for Testing Materials

GAS IGNITION TEMPERATURES AND EXPLOSIVE LIMITS IN AIR

Gas or Vapor	Ignition Temperature °F	Explosive Limits Lower Limit % by Volume	Upper Limit % by Volume
Carbon Monoxide	1204	12.5	74.0
Hydrogen	1085	4.1	74.2
Methane	999	5.3	14.0
Ethane	950	3.2	12.5
Propane	871	2.37	9.5
n-Butane	806	1.6	8.5
iso-Butane	1010	1.9	8.5
Pentane	588	1.45	7.5
Hexane	500	1.2	6.9
Ethylene	842	2.75	28.6
Propylene	927	2.0	11.1
Benzene	1000	1.5	8.0
Toluene	1026	1.27	7.0
Xylene	900	1.0	5.3
Acetylene	581*	2.5	80.
Naphthalene	1038	0.9	
Ammonia	1204	16.	25.
Hydrogen Sulphide	500	4.3	46.0

National Fire Protection Association excerpt from Bureau of Mines Report of Investigations 3567.

SAFE END-POINTS IN PURGING OPERATIONS INVOLVING VARIOUS COMBUSTIBLE AND INERT GASES

Combustible Gas or Vapor	Inert Gas	Safe End Point—% by Volume: Purging from Air to Gas Maximum Permissible Oxygen Content of Atmosphere in Container	Purging from Gas to Air Maximum Permissible Combustible Gas Content of Atmosphere in Container
Mixed Gas	Nitrogen	8.6	11.0
Carburetted Blue Gas	Nitrogen	8.0	11.8
Coal Gas	Nitrogen	9.0	10.0
Benzol Vapor	Nitrogen	11.6	4.8
Hydrogen	Carbon Dioxide	8.1	8.9
	Nitrogen	5.1	5.7
Carbon Monoxide	Carbon Dioxide	9.8	31.5
	Nitrogen	6.6	19.5
Methane	Carbon Dioxide	15.7	22.6
	Nitrogen	12.8	14.0
Ethane	Carbon Dioxide	14.0	11.7
	Nitrogen	11.4	7.2
Propane	Carbon Dioxide	14.9	10.8
	Nitrogen	11.9	6.4
Butane	Carbon Dioxide	15.0	9.2
	Nitrogen	12.4	5.6
Ethylene	Carbon Dioxide	12.2	10.0
	Nitrogen	10.3	6.3

S. S. Tomkins.

CALCULATING EXPLOSIVE LIMITS OF GAS MIXTURES IN AIR

Coward and his co-workers have arranged the Le Chatelier formula in the following form for calculating the limits in air of any mixture of combustible gases to which it is applicable:

$$L = \frac{100}{\frac{P_1}{N_1} + \frac{P_2}{N_2} + \frac{P_3}{N_3} + \cdots}$$

Where P_1, P_2 and P_3 are the proportions of each combustible gas present in the original mixture, free from air and inert gases so that

$$P_1 + P_2 + P_3 + \cdots = 100$$

and N_1, N_2, N_3 are the limits in air for each gas separately, no inert gases being present.

EXPLOSIVE LIMITS OF SELECTED INDUSTRIAL GASES IN AIR

Kind of Gas	Heating Value, B.t.u./ Cu. Ft.	Composition—% by Volume: CO_2	Ill.	O_2	CO	H_2	CH_4	C_2H_6	N_2	Explosive Limits Lower	Upper
Blue	310	6.2	0.0	0.3	39.2	49.0	2.3		3.0	6.9	69.5
	308	1.9	0.0	0.3	45.0	47.5	1.2		4.1	6.1	67.4
Carburetted	509	4.6	7.3	0.3	36.0	37.0	9.6		5.2	6.4	37.7
Blue	538	3.9	8.2	0.7	32.4	33.7	13.1		8.0	6.8	37.3
	541	5.7	10.2	0.7	26.1	28.3	8.1	1.9	19.0	7.3	31.6
Coal	549	2.4	2.7	0.4	9.7	44.9	28.9		11.0	5.6	30.8
		1.6	3.1	1.2	8.5	50.3	26.0		9.3	5.8	29.0
Coke Oven	631	1.9	3.9	0.4	6.3	54.4	31.5		1.6	5.0	28.4
	540	2.5	3.4	0.8	11.1	47.9	24.2		10.1	5.3	30.0
	547	2.3	4.0	1.5	7.8	46.8	24.6	1.0	12.0	6.0	28.4
"Mixed"	540	2.5	3.2	0.5	10.5	47.0	25.8		10.5	5.6	31.7
	540	3.8	5.7	1.3	22.4	38.5	18.1		10.2	6.3	34.0
	540	3.1	8.1	0.8	21.5	33.7	15.0	1.0	16.8	6.8	30.8
Producer	136	6.2	0.0	0.0	27.3	12.4	0.7		53.4	20.7	73.7
	118	5.4	0.0	0.0	26.6	9.3	0.4		58.3	18.6	*
Natural										4.8	13.5

S. S. Tomkins.

LAWS OF PERFECT GASES

A perfect gas is defined as one which obeys exactly the laws of Boyle, Charles, Joule and Avogadro. Actually there are no perfect gases, but air, oxygen, nitrogen and hydrogen are among those which conform closely to the above laws, except at very low temperatures.

Boyle's Law

When the temperature of a given weight of a perfect gas is held constant the volume and absolute pressure vary inversely.

That is $PV = C$ (a constant).

where P = Absolute pressure of the gas.
V = Specific volume of the gas.
t = Absolute temperature of the gas.

Also $PV = P_1V_1 = P_2V_2$ if $t = t_1 = t_2$

Charles' Law

When a perfect gas receives heat at constant volume, the absolute pressure varies directly as the absolute temperature. That is

$$\frac{P}{T} = C_1 \text{ (a constant)}$$

Also $\frac{P}{T} = \frac{P_1}{T_1} = \frac{P_2}{T_2}$ if $V = V_1 = V_2$.

Also $\frac{PV}{T} = \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$.

Joule's Law

The internal energy of a perfect gas is a function of the temperature only. Thus mathematically, if a gas obeys Boyle's and Charles' laws, it must also obey Joule's law.

Avogadro's Law

Equal volumes of all perfect gases measured under the same temperature and pressure conditions contain the same number of molecules.

Dalton's Law of Partial Pressures

In a mixture of gases, each gas taken alone exerts a partial pressure equal to the pressure that it would exert if the same weight that is actually present in the mixture were present alone in the volume in question.

Characteristic Equation for a Perfect Gas

In the case of a perfect gas, the laws of Boyle and Charles may be combined into a single equation as follows:

$PV = MRT$

where P = absolute pressure (lbs. per sq. ft.)
V = volume of M pounds of gas at pressure P and temperature T (cu. ft.)
M = weight of the gas (lbs.)
R = gas constant of the particular gas (ft. lbs. per lb. per degree F.)
T = absolute temperature of the gas (degrees F.)

Example R for oxygen $= \frac{14.735 \times 144 \times 11.817}{1 \times (60° + 459.7°)}$
$= 48.25$ ft. lbs. per lb. per degree F.

(For cubic feet of oxygen per pound at 60° F. and 30 inches of mercury pressure, see page 24.)

Then 10 pounds of oxygen under a pressure of 200 lbs. per sq. in. gauge and a temperature of 100° F. would occupy the following volume:

$$V = \frac{10 \times 48.25\ (100 + 459.7)}{(200 + 14.696) \times 144} = 8.74 \text{ cu. ft.}$$

If it were then expanded to a volume of 80 cubic feet and 5 lbs. per sq. in. gauge pressure, the temperature would be reduced to:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{214.696 \times 144 \times 8.74}{559.7} = \frac{19.696 \times 144 \times 80}{T_2}$$

$T_2 = 470.0°$ F. absolute
$= 10.3°$ F.

The Pound Mol

This unit may be defined as the number of pounds of a given substance equal to the molecular weight of the substance.

One pound mol of all perfect gases at any given temperature and pressure will occupy the same volume. At 60° F. and 30 inches of mercury pressure the figure is 378.4 cubic feet for dry gas and 385 cubic feet for saturated gas.

As indicated in the table (below) there is always some departure from this figure, since there are no gases which obey Boyle's Law exactly.

The Universal Gas Constant

In a similar way, if M in the equation $PV = MRT$ be taken as equal to one pound mol, then $M \times R$ will equal a constant for all perfect gases. For the different units employed these will be:

Basis	*Lb. mol*	*Lb. mol*	*Lb. mol*	*Gram mol*
P(abs.)	Lbs. per sq. ft.	Lbs. per sq. in.	Inches of Hg.	Mm. of Hg.
V	Cu. ft.	Cu. ft.	Cu. ft.	Liters
T(abs.)	°F.	°F.	°F.	°C.
MR	1545	10.73	21.85	62.37

VALUES OF R AND THE GAS CONSTANT MR AND VOLUMES OF THE POUND MOL FOR CERTAIN GASES.

	R Ft.-Lbs. per lb. per degree F.	M Pound Mol.	MR The Gas Constant	Cubic Feet per Mol.
Hydrogen	767.04	2.016	1,546	378.8
Oxygen	48.24	32.000	1,544	378.1
Nitrogen	55.13	28.016	1,545	378.3
Nitrogen "Atmospheric"	54.85	28.161	1,545	378.4
Air	53.33	28.97	1,545	378.4
Water Vapor	85.72	18.016	1,544	378.2
Carbon Dioxide	34.87	44.010	1,535	375.9
Carbon Monoxide	55.14	28.010	1,544	378.2
Hyrodgen Sulphide	44.79	34.076	1,526	373.9
Sulphur Dioxide	23.56	64.060	1,509	369.6
Ammonia	89.42	17.032	1,523	373.1
Methane	96.18	16.042	1,543	377.9
Ethane	50.82	30.068	1,528	374.3
Propane	34.13	44.094	1,505	368.6
n-Butane	25.57	58.120	1,486	364.0
Iso-Butane	25.79	58.120	1,499	367.1
Ethylene	54.70	28.052	1,534	375.8
Propylene	36.01	42.078	1,515	371.1

CORRECTING GAS VOLUME FOR PRESSURE AND TEMPERATURE

(Multiply observed volume of saturated gas by factor to reduce to volume of saturated gas at 60 F. and under a pressure of 30 inches of mercury at 32 F.) National Bureau of Standards Circular 464—1948.

Temperature, ° F	Total gas pressure—Inches of mercury										Total gas pressure—Inches of mercury																° F
	28.0	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5	
32	0.9975	1.0011	1.0047	1.0083	1.0118	1.0154	1.0190	1.0226	1.0262	1.0298	1.0334	1.0369	1.0405	1.0441	1.0477	1.0513	1.0549	1.0585	1.0620	1.0656	1.0692	1.0728	1.0764	1.0800	1.0836	1.0871	32
33	.9952	0.9988	1.0023	1.0059	1.0095	1.0131	1.0166	1.0202	1.0238	1.0274	1.0310	1.0345	1.0381	1.0417	1.0453	1.0488	1.0524	1.0560	1.0596	1.0632	1.0667	1.0703	1.0739	1.0775	1.0811	1.0846	33
34	.9929	.9965	1.0001	1.0036	1.0072	1.0108	1.0143	1.0179	1.0215	1.0251	1.0286	1.0322	1.0358	1.0393	1.0429	1.0465	1.0501	1.0536	1.0572	1.0608	1.0643	1.0679	1.0715	1.0751	1.0786	1.0822	34
35	.9906	.9941	0.9977	1.0013	1.0048	1.0084	1.0120	1.0155	1.0191	1.0227	1.0262	1.0298	1.0333	1.0369	1.0405	1.0440	1.0476	1.0512	1.0547	1.0583	1.0619	1.0654	1.0690	1.0725	1.0761	1.0797	35
36	.9883	.9919	.9955	0.9990	1.0026	1.0061	1.0097	1.0132	1.0168	1.0204	1.0239	1.0275	1.0310	1.0346	1.0381	1.0417	1.0453	1.0488	1.0524	1.0559	1.0595	1.0630	1.0666	1.0702	1.0737	1.0773	36
37	.9860	.9896	.9931	.9967	1.0002	1.0038	1.0073	1.0109	1.0144	1.0180	1.0215	1.0251	1.0286	1.0322	1.0357	1.0393	1.0428	1.0464	1.0499	1.0535	1.0570	1.0606	1.0641	1.0676	1.0712	1.0747	37
38	.9838	.9873	.9908	.9944	0.9979	1.0015	1.0050	1.0086	1.0121	1.0156	1.0192	1.0227	1.0263	1.0298	1.0333	1.0369	1.0404	1.0440	1.0475	1.0511	1.0546	1.0581	1.0617	1.0652	1.0688	1.0723	38
39	.9815	.9850	.9886	.9921	.9956	0.9992	1.0027	1.0062	1.0098	1.0133	1.0168	1.0204	1.0239	1.0274	1.0310	1.0345	1.0381	1.0416	1.0451	1.0487	1.0522	1.0557	1.0593	1.0628	1.0663	1.0699	39
40	.9791	.9827	.9862	.9897	.9932	.9968	1.0003	1.0038	1.0074	1.0109	1.0144	1.0179	1.0215	1.0250	1.0285	1.0320	1.0356	1.0391	1.0426	1.0462	1.0497	1.0532	1.0567	1.0603	1.0638	1.0673	40
41	.9768	.9803	.9839	.9874	.9909	.9944	0.9979	1.0015	1.0050	1.0085	1.0120	1.0155	1.0191	1.0226	1.0261	1.0296	1.0331	1.0367	1.0402	1.0437	1.0472	1.0508	1.0543	1.0578	1.0613	1.0648	41
42	.9745	.9781	.9816	.9851	.9886	.9921	.9956	0.9991	1.0027	1.0062	1.0097	1.0132	1.0167	1.0202	1.0237	1.0272	1.0308	1.0343	1.0378	1.0413	1.0448	1.0483	1.0518	1.0554	1.0589	1.0624	42
43	.9722	.9757	.9792	.9827	.9862	.9897	.9932	.9968	1.0003	1.0038	1.0073	1.0108	1.0143	1.0178	1.0213	1.0248	1.0283	1.0318	1.0353	1.0388	1.0423	1.0459	1.0494	1.0529	1.0564	1.0599	43
44	.9699	.9734	.9769	.9804	.9839	.9874	.9909	.9944	0.9979	1.0014	1.0049	1.0084	1.0119	1.0154	1.0189	1.0224	1.0259	1.0294	1.0329	1.0364	1.0399	1.0434	1.0469	1.0504	1.0539	1.0574	44
45	.9676	.9711	.9746	.9781	.9816	.9850	.9885	.9920	.9955	0.9990	1.0025	1.0060	1.0095	1.0130	1.0165	1.0200	1.0235	1.0270	1.0305	1.0339	1.0374	1.0409	1.0444	1.0479	1.0514	1.0549	45
46	.9653	.9688	.9723	.9757	.9792	.9827	.9862	.9897	.9932	.9967	1.0001	1.0036	1.0071	1.0106	1.0141	1.0176	1.0211	1.0246	1.0280	1.0315	1.0350	1.0385	1.0420	1.0455	1.0490	1.0524	46
47	.9629	.9664	.9699	.9734	.9768	.9803	.9838	.9873	.9908	.9942	0.9977	1.0012	1.0047	1.0082	1.0116	1.0151	1.0186	1.0221	1.0256	1.0290	1.0325	1.0360	1.0395	1.0430	1.0464	1.0499	47
48	.9606	.9641	.9676	.9710	.9745	.9780	.9815	.9849	.9884	.9919	.9953	0.9988	1.0023	1.0058	1.0092	1.0127	1.0162	1.0196	1.0231	1.0266	1.0301	1.0335	1.0370	1.0405	1.0440	1.0474	48
49	.9583	.9617	.9652	.9687	.9721	.9756	.9791	.9825	.9860	.9895	.9929	.9964	0.9998	1.0033	1.0068	1.0102	1.0137	1.0172	1.0206	1.0241	1.0276	1.0310	1.0345	1.0380	1.0414	1.0449	49
50	.9560	.9594	.9629	.9663	.9698	.9732	.9767	.9802	.9836	.9871	.9905	.9940	.9975	1.0009	1.0044	1.0078	1.0113	1.0148	1.0182	1.0217	1.0251	1.0286	1.0320	1.0355	1.0390	1.0424	50
51	.9536	.9570	.9605	.9639	.9674	.9708	.9743	.9777	.9812	.9846	.9881	.9915	.9950	0.9984	1.0019	1.0054	1.0088	1.0123	1.0157	1.0192	1.0226	1.0261	1.0295	1.0330	1.0364	1.0399	51
52	.9513	.9547	.9582	.9616	.9650	.9685	.9719	.9754	.9788	.9823	.9857	.9892	.9926	.9961	0.9995	1.0029	1.0064	1.0098	1.0133	1.0167	1.0202	1.0236	1.0271	1.0305	1.0340	1.0374	52
53	.9489	.9523	.9557	.9592	.9626	.9660	.9695	.9729	.9764	.9798	.9832	.9867	.9901	.9936	.9970	1.0004	1.0039	1.0073	1.0107	1.0142	1.0176	1.0211	1.0245	1.0279	1.0314	1.0348	53
54	.9465	.9499	.9534	.9568	.9602	.9637	.9671	.9705	.9740	.9774	.9808	.9843	.9877	.9911	.9946	0.9980	1.0014	1.0049	1.0083	1.0117	1.0151	1.0186	1.0220	1.0254	1.0289	1.0323	54
55	.9442	.9476	.9510	.9545	.9579	.9613	.9647	.9682	.9716	.9750	.9784	.9819	.9853	.9887	.9921	.9956	0.9990	1.0024	1.0058	1.0093	1.0127	1.0161	1.0195	1.0230	1.0264	1.0298	55
56	.9418	.9452	.9486	.9520	.9554	.9589	.9623	.9657	.9691	.9725	.9759	.9794	.9828	.9862	.9896	.9930	.9965	0.9999	1.0033	1.0067	1.0101	1.0135	1.0170	1.0204	1.0238	1.0272	56
57	.9394	.9428	.9462	.9496	.9531	.9565	.9599	.9633	.9667	.9701	.9735	.9769	.9803	.9838	.9872	.9906	.9940	.9974	1.0008	1.0042	1.0076	1.0111	1.0145	1.0179	1.0213	1.0247	57
58	.9370	.9404	.9438	.9472	.9506	.9540	.9574	.9608	.9642	.9676	.9710	.9744	.9778	.9812	.9846	.9881	.9915	.9949	0.9983	1.0017	1.0051	1.0085	1.0119	1.0153	1.0187	1.0221	58
59	.9346	.9380	.9414	.9448	.9482	.9516	.9550	.9584	.9618	.9652	.9686	.9720	.9754	.9788	.9822	.9856	.9890	.9924	.9958	0.9992	1.0026	1.0060	1.0094	1.0128	1.0162	1.0196	59
60	.9321	.9355	.9389	.9423	.9457	.9491	.9525	.9559	.9593	.9627	.9661	.9695	.9729	.9762	.9796	.9830	.9864	.9898	.9932	.9966	1.0000	1.0034	1.0068	1.0102	1.0136	1.0170	60
61	.9297	.9331	.9365	.9399	.9433	.9467	.9501	.9534	.9568	.9602	.9636	.9670	.9704	.9738	.9772	.9805	.9839	.9873	.9907	.9941	0.9975	1.0009	1.0042	1.0076	1.0110	1.0144	61
62	.9273	.9307	.9340	.9374	.9408	.9442	.9476	.9509	.9543	.9577	.9611	.9644	.9678	.9712	.9746	.9780	.9813	.9847	.9881	.9915	.9949	0.9982	1.0016	1.0050	1.0084	1.0118	62
63	.9248	.9282	.9316	.9350	.9383	.9417	.9451	.9485	.9518	.9552	.9586	.9619	.9653	.9687	.9721	.9754	.9788	.9822	.9856	.9889	.9923	.9957	0.9990	1.0024	1.0058	1.0092	63
64	.9224	.9257	.9291	.9325	.9358	.9392	.9426	.9459	.9493	.9527	.9560	.9594	.9628	.9661	.9695	.9729	.9762	.9796	.9830	.9863	.9897	.9931	.9964	0.9998	1.0032	1.0065	64
65	.9199	.9233	.9266	.9300	.9334	.9367	.9401	.9434	.9468	.9502	.9535	.9569	.9602	.9636	.9670	.9703	.9737	.9770	.9804	.9838	.9871	.9905	.9938	.9972	1.0006	1.0039	65
66	.9174	.9208	.9241	.9275	.9308	.9342	.9375	.9409	.9442	.9476	.9509	.9543	.9576	.9610	.9644	.9677	.9711	.9744	.9778	.9811	.9845	.9878	.9912	.9945	0.9979	1.0012	66
67	.9149	.9183	.9216	.9250	.9283	.9317	.9350	.9383	.9417	.9450	.9484	.9517	.9551	.9584	.9618	.9651	.9685	.9718	.9752	.9785	.9819	.9852	.9886	.9919	.9953	0.9986	67
68	.9124	.9157	.9190	.9224	.9257	.9291	.9324	.9357	.9391	.9424	.9458	.9491	.9524	.9558	.9591	.9625	.9658	.9692	.9725	.9758	.9792	.9825	.9859	.9892	.9925	.9959	68
69	.9099	.9132	.9165	.9199	.9232	.9265	.9299	.9332	.9365	.9399	.9432	.9465	.9499	.9532	.9566	.9599	.9632	.9666	.9699	.9732	.9766	.9799	.9832	.9866	.9899	.9932	69
70	.9073	.9106	.9139	.9173	.9206	.9239	.9273	.9306	.9339	.9372	.9406	.9439	.9472	.9506	.9539	.9572	.9605	.9639	.9672	.9705	.9739	.9772	.9805	.9838	.9872	.9905	70

Temperature, ° F	Total gas pressure—Inches of mercury										Total gas pressure—Inches of mercury																° F
	28.0	28.1	28.2	28.3	28.4	28.5	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.2	30.3	30.4	30.5	
71	0.9048	0.9081	0.9114	0.9147	0.9180	0.9214	0.9247	0.9280	0.9313	0.9346	0.9380	0.9413	0.9446	0.9479	0.9513	0.9546	0.9579	0.9612	0.9645	0.9679	0.9712	0.9745	0.9778	0.9812	0.9845	0.9878	71
72	.9022	.9055	.9088	.9121	.9154	.9188	.9221	.9254	.9287	.9320	.9353	.9387	.9420	.9453	.9486	.9519	.9552	.9586	.9619	.9652	.9685	.9718	.9751	.9784	.9818	.9851	72
73	.8996	.9029	.9062	.9095	.9128	.9161	.9194	.9228	.9261	.9294	.9327	.9360	.9393	.9426	.9459	.9492	.9525	.9559	.9592	.9625	.9658	.9691	.9724	.9757	.9790	.9823	73
74	.8970	.9003	.9036	.9069	.9102	.9135	.9168	.9201	.9234	.9267	.9300	.9333	.9366	.9399	.9432	.9465	.9498	.9531	.9564	.9597	.9630	.9664	.9697	.9730	.9763	.9796	74
75	.8944	.8977	.9010	.9043	.9076	.9108	.9141	.9174	.9207	.9240	.9273	.9306	.9339	.9372	.9405	.9438	.9471	.9504	.9537	.9570	.9603	.9636	.9669	.9702	.9735	.9768	75
76	.8917	.8950	.8983	.9015	.9048	.9081	.9114	.9147	.9180	.9213	.9246	.9279	.9312	.9345	.9377	.9410	.9443	.9476	.9509	.9542	.9575	.9608	.9641	.9674	.9707	.9739	76
77	.8890	.8923	.8956	.8989	.9022	.9055	.9088	.9120	.9153	.9186	.9219	.9252	.9285	.9318	.9350	.9383	.9416	.9449	.9482	.9515	.9547	.9580	.9613	.9646	.9679	.9712	77
78	.8864	.8897	.8930	.8962	.8995	.9028	.9061	.9094	.9126	.9159	.9192	.9225	.9257	.9290	.9323	.9356	.9389	.9421	.9454	.9487	.9520	.9553	.9585	.9618	.9651	.9684	78
79	.8837	.8870	.8902	.8935	.8968	.9000	.9033	.9066	.9099	.9131	.9164	.9197	.9230	.9262	.9295	.9328	.9361	.9393	.9426	.9459	.9491	.9524	.9557	.9590	.9622	.9655	79
80	.8810	.8842	.8875	.8908	.8940	.8973	.9006	.9038	.9071	.9104	.9136	.9169	.9202	.9234	.9267	.9300	.9332	.9365	.9398	.9430	.9463	.9496	.9528	.9561	.9594	.9626	80
81	.8782	.8815	.8847	.8880	.8912	.8945	.8978	.9010	.9043	.9075	.9108	.9141	.9173	.9206	.9238	.9271	.9304	.9336	.9369	.9401	.9434	.9467	.9499	.9532	.9564	.9597	81
82	.8754	.8787	.8819	.8852	.8884	.8917	.8950	.8982	.9015	.9047	.9080	.9112	.9145	.9177	.9210	.9242	.9275	.9308	.9340	.9373	.9405	.9438	.9470	.9503	.9535	.9568	82
83	.8726	.8759	.8791	.8824	.8856	.8889	.8921	.8954	.8986	.9019	.9051	.9083	.9116	.9148	.9181	.9213	.9246	.9278	.9311	.9343	.9376	.9408	.9441	.9473	.9506	.9538	83
84	.8698	.8731	.8763	.8796	.8828	.8861	.8893	.8925	.8958	.8990	.9023	.9055	.9088	.9120	.9152	.9185	.9217	.9250	.9282	.9315	.9347	.9379	.9412	.9444	.9477	.9509	84
85	.8670	.8702	.8734	.8767	.8799	.8832	.8864	.8896	.8929	.8961	.8993	.9026	.9058	.9090	.9123	.9155	.9188	.9220	.9252	.9285	.9317	.9349	.9382	.9414	.9447	.9479	85
86	.8641	.8674	.8706	.8738	.8771	.8803	.8835	.8868	.8900	.8932	.8965	.8997	.9029	.9061	.9094	.9126	.9158	.9191	.9223	.9255	.9288	.9320	.9352	.9385	.9417	.9449	86
87	.8612	.8644	.8677	.8709	.8741	.8773	.8806	.8838	.8870	.8902	.8935	.8967	.8999	.9031	.9064	.9096	.9128	.9160	.9193	.9225	.9257	.9289	.9322	.9354	.9386	.9418	87
88	.8583	.8615	.8648	.8680	.8712	.8744	.8776	.8808	.8841	.8873	.8905	.8937	.8969	.9002	.9034	.9066	.9098	.9130	.9163	.9195	.9227	.9259	.9291	.9324	.9356	.9388	88
89	.8554	.8586	.8618	.8650	.8682	.8714	.8746	.8779	.8811	.8843	.8875	.8907	.8939	.8971	.9004	.9036	.9068	.9100	.9132	.9164	.9196	.9228	.9261	.9293	.9325	.9357	89
90	.8524	.8556	.8588	.8620	.8652	.8685	.8717	.8749	.8781	.8813	.8845	.8877	.8909	.8941	.8973	.9005	.9037	.9069	.9101	.9134	.9166	.9198	.9230	.9262	.9294	.9326	90
91	.8494	.8526	.8558	.8590	.8622	.8654	.8686	.8718	.8750	.8782	.8814	.8846	.8878	.8910	.8942	.8974	.9006	.9038	.9070	.9102	.9134	.9166	.9198	.9230	.9262	.9294	91
92	.8464	.8496	.8528	.8560	.8592	.8624	.8656	.8688	.8720	.8752	.8784	.8816	.8848	.8879	.8911	.8943	.8975	.9007	.9039	.9071	.9103	.9135	.9167	.9199	.9231	.9263	92
93	.8433	.8465	.8497	.8529	.8561	.8593	.8625	.8656	.8688	.8720	.8752	.8784	.8816	.8848	.8880	.8912	.8944	.8976	.9008	.9039	.9071	.9103	.9135	.9167	.9199	.9231	93
94	.8403	.8434	.8466	.8498	.8530	.8562	.8594	.8625	.8657	.8689	.8721	.8753	.8785	.8816	.8848	.8880	.8912	.8944	.8976	.9008	.9039	.9071	.9103	.9135	.9167	.9199	94
95	.8371	.8403	.8435	.8467	.8498	.8530	.8562	.8594	.8626	.8657	.8689	.8721	.8753	.8784	.8816	.8848	.8880	.8912	.8943	.8975	.9007	.9039	.9070	.9102	.9134	.9166	95
96	.8340	.8372	.8404	.8435	.8467	.8499	.8530	.8562	.8594	.8626	.8657	.8689	.8721	.8753	.8784	.8816	.8848	.8879	.8911	.8943	.8975	.9006	.9038	.9070	.9102	.9133	96
97	.8308	.8340	.8371	.8403	.8435	.8466	.8498	.8530	.8561	.8593	.8625	.8656	.8688	.8720	.8751	.8783	.8815	.8846	.8878	.8910	.8941	.8973	.9005	.9036	.9068	.9100	97
98	.8276	.8308	.8339	.8371	.8403	.8434	.8466	.8497	.8529	.8561	.8592	.8624	.8655	.8687	.8719	.8750	.8782	.8814	.8845	.8877	.8908	.8940	.8972	.9003	.9035	.9066	98
99	.8243	.8275	.8306	.8338	.8370	.8401	.8433	.8465	.8496	.8527	.8559	.8590	.8622	.8653	.8685	.8717	.8748	.8780	.8811	.8843	.8874	.8906	.8937	.8969	.9001	.9032	99
100	.8211	.8243	.8274	.8306	.8337	.8369	.8400	.8432	.8463	.8495	.8526	.8558	.8589	.8621	.8652	.8684	.8715	.8747	.8778	.8810	.8841	.8873	.8904	.8936	.8967	.8999	100
101	.8178	.8209	.8241	.8272	.8304	.8335	.8367	.8398	.8430	.8461	.8492	.8524	.8555	.8587	.8618	.8650	.8681	.8713	.8744	.8775	.8807	.8838	.8870	.8901	.8933	.8964	101
102	.8144	.8176	.8207	.8238	.8270	.8301	.8333	.8364	.8395	.8427	.8458	.8489	.8521	.8552	.8584	.8615	.8646	.8678	.8709	.8741	.8772	.8803	.8835	.8866	.8897	.8929	102
103	.8110	.8142	.8173	.8204	.8236	.8267	.8298	.8330	.8361	.8392	.8424	.8455	.8486	.8518	.8549	.8580	.8612	.8643	.8674	.8706	.8737	.8768	.8800	.8831	.8862	.8894	103
104	.8076	.8107	.8138	.8170	.8201	.8232	.8263	.8295	.8326	.8357	.8389	.8420	.8451	.8482	.8514	.8545	.8576	.8607	.8639	.8670	.8701	.8733	.8764	.8795	.8826	.8858	104
105	.8041	.8072	.8104	.8135	.8166	.8197	.8229	.8260	.8291	.8322	.8353	.8385	.8416	.8447	.8478	.8510	.8541	.8572	.8603	.8634	.8666	.8697	.8728	.8759	.8791	.8822	105
106	.8006	.8037	.8069	.8100	.8131	.8162	.8193	.8224	.8256	.8287	.8318	.8349	.8380	.8411	.8443	.8474	.8505	.8536	.8567	.8598	.8630	.8661	.8692	.8723	.8754	.8785	106
107	.7971	.8002	.8033	.8064	.8095	.8126	.8157	.8188	.8220	.8251	.8282	.8313	.8344	.8375	.8406	.8437	.8468	.8500	.8531	.8562	.8593	.8624	.8655	.8686	.8717	.8748	107
108	.7935	.7966	.7997	.8028	.8059	.8090	.8121	.8152	.8183	.8214	.8245	.8276	.8307	.8339	.8370	.8401	.8432	.8463	.8494	.8525	.8556	.8587	.8618	.8649	.8680	.8711	108
109	.7899	.7930	.7961	.7992	.8023	.8054	.8085	.8116	.8147	.8178	.8209	.8240	.8271	.8302	.8333	.8364	.8395	.8426	.8457	.8488	.8519	.8550	.8581	.8612	.8643	.8674	109
110	.7862	.7893	.7924	.7954	.7985	.8016	.8047	.8078	.8109	.8140	.8171	.8202	.8233	.8264	.8295	.8326	.8357	.8388	.8419	.8450	.8481	.8511	.8542	.8573	.8604	.8635	110

[1] **Formula used:** Correction factor $= \frac{(p - w_t)(60 + 459.7)}{(t + 459.8)(30 - 0.5217)}$

p = total gas pressure; w_t = vapor pressure of water at $t°$; t = temperature of gas (°F).

VAPOR PRESSURES, POUNDS PER SQUARE INCH ABSOLUTE

Temperature, °F	Acetylene, C_2H_2	Ammonia, NH_3	Benzene, C_6H_6	*n*-Butane, C_4H_{10}	Isobutane, C_4H_{10}	Carbon Dioxide, CO_2	Carbon Disulfide, CS_2	Ethane, C_2H_6	Ethyl Alcohol, C_2H_5OH	Ethyl Chloride C_2H_5Cl	Hydrogen Sulfide, H_2S	Methyl Chloride, CH_3Cl	Naphthalene, $C_{10}H_8$ Dry	Naphthalene, $C_{10}H_8$ Moist	Propane, C_3H_8	Sulfur dioxide, SO_2	Toluene, C_7H_8	Water, H_2O	*m*-Xylene, C_8H_{10}
−20	162	18.30	...	...	7.50	215.02	0.53	158	0.022	2.16	57.5	11.75	....	....	25.4	5.883	...	....	...
−10	196	23.74	...	...	9.28	257.46	0.74	185	0.036	2.94	70.0	15.0	....	....	31.4	7.863	...	....	...
0	232	30.42	...	7.3	12.1	305.5	1.00	218	0.058	3.93	84.0	18.8	....	....	38.2	10.35	...	....	...
10	271	38.51	...	9.3	14.8	360.2	1.36	250	0.090	5.13	100	23.3	....	....	46.5	13.42	...	....	...
20	319	48.21	...	11.8	18.2	421.8	1.80	290	0.140	6.65	120	28.8	....	....	55.5	17.18	...	....	...
30	372	59.74	[a] 0.48	14.4	23.3	490.8	2.30	334	0.220	8.40	143	35.2	0.000096	0.000029	66.3	21.70	0.125	....	0.031
32	387	62.29	0.52	15.8	23.2	505.5	2.46	346	0.236	8.85	150	36.6	0.00011	0.000033	68.0	22.47	0.137	0.0887	0.034
40	430	73.32	0.66	18.4	26.9	567.8	2.96	381	0.330	10.53	169	42.6	0.00018	0.000057	78.0	27.10	0.176	0.1217	0.042
50	495	89.19	0.88	22.7	32.2	653.6	3.83	418	0.456	13.20	197	51.5	0.00034	0.00012	91.8	33.45	0.247	0.1780	0.061
60	565	107.6	1.14	27.1	38.7	748.6	4.75	496	0.640	16.5	230	61.6	0.00060	0.00026	107.1	40.93	0.335	0.2561	0.093
70	645	128.8	1.51	32.7	45.8	853.4	5.93	560	0.910	20.0	267	73.3	0.0011	0.00057	124.0	49.62	0.455	0.3628	0.131
80	735	153.0	1.95	39.0	53.9	968.7	7.30	632	1.25	24.3	302	85.3	0.0019	0.0013	142.8	59.68	0.607	0.5067	0.178
90	830	180.6	2.51	46.2	63.3	....	9.00	708	1.71	29.0	344	102.1	0.0032	0.0029	164.0	71.25	0.790	0.6980	0.241
100	..	211.9	3.20	55.0	74.7	....	10.8	..	2.32	34.9	392	118.8	0.0054	0.0054	187.0	84.52	1.03	0.9487	0.330
110	..	247.0	[b] 4.05	64.2	85.1	....	13.3	..	3.09	41.1	442	137.6	0.0088	0.0094	212.0	99.76	1.32	1.274	0.435
120	..	286.4	4.22	75	98.0	....	16.0	..	4.02	48.1	500	158.8	0.0142	0.016	240.0	120.9	1.70	1.692	0.570
130	..	329	6.41	87	112.0	....	19.0	..	5.27	56.3	560	173	0.0218	....	272	135.0	2.13	2.221	0.745
140	..	379	7.53	101	126.8	....	22.6	..	6.82	66.1	632	200	0.0322	....	...	157.8	2.70	2.887	0.978
150	..	435	9.2	115	....	....	26.5	..	8.65	76.0	700	223	0.0439	....	...	181	3.30	3.716	1.22
160	..	495	11.0	132	....	....	30.9	..	10.9	86.3	778	253	0.071	....	...	209	4.03	4.739	1.53
170	..	560	13.0	151	....	....	35.9	..	13.5	99.0	862	287	0.105	....	...	239	5.00	5.990	1.94
180	..	640	15.4	172	....	....	41.9	..	17.0	113	962	322	0.155	....	...	272	6.02	7.510	2.42
190	..	715	18.2	194	....	....	48.0	..	21.0	127	1050	360	0.217	....	...	309	7.3	9.336	2.98
200	..	800	21.7	219	....	....	55.2	..	25.5	142	1160	400	0.277	....	...	350	8.7	11.525	3.62
210	..	890	25.4	248	....	....	63.0	..	31.1	161	1280	445	0.347	....	...	399	10.3	14.123	4.42
220	..	990	...	...	....	....	71.5	..	37.8	180	....	495	0.419	....	...	449	...	17.188	5.30
230	..	1100	...	...	....	....	81.6	..	45.7	203	....	550	0.547	....	...	501	...	20.78	6.35
240	..	1210	...	...	....	....	91.8	..	54.5	230	....	605	0.68	....	...	561	...	24.97	7.55
250	..	1340	...	...	....	....	103	..	64.5	260	....	670	0.85	....	...	624	...	29.82	9.0
	[d]	[d, h]	[b, d]	[b, c, f]	[c, f]	[d, a, f]	[d]	[d]	[d]	[d, f]	[d]	[d, e]	[b, d]	[b]	[c, f]	[d, f]	[a, d]	[g]	[d]

[a] Gas Chemists Handbook, Third Edition, 1929.
[b] Gas Engineers' Handook, First Edition, 1934.
[c] Handbook of Butane-Propane Gases, Second Edition, 1935.
[d] Handbook of Chemistry and Physics, Nineteenth Edition, 1934.
[e] *Heating and Ventilating*, September and October 1938.
[f] L. S. Marks, Mechanical Engineers' Handbook, Third Edition, 1930.
[g] J. H. Keenan, "Steam Tables and Mollier Diagram," 1930.
[h] U. S. Bur. of Standards, Circular No. 142, 1923.

Note: Over small temperature intervals the logarithm of the vapor pressure plotted against temperature is practically a straight line. For longer temperature intervals the plot against reciprocal of the absolute temperature should be used.

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REDUCTION OF BAROMETRIC READINGS

This table gives the corrections in inches of mercury to convert readings at various temperatures to readings at standard temperature.

°F.	Observed reading of barometer in inches						
	24	25	26	27	28	29	30
0	+0.063	+0.065	+0.068	+0.070	+0.073	+0.076	+0.078
2	+0.058	+0.061	+0.063	+0.065	+0.068	+0.070	+0.073
4	+0.054	+0.056	+0.058	+0.061	+0.063	+0.065	+0.067
6	+0.049	+0.052	+0.054	+0.056	+0.058	+0.060	+0.062
8	+0.045	+0.047	+0.049	+0.051	+0.053	+0.054	+0.056
10	+0.041	+0.042	+0.044	+0.046	+0.047	+0.049	+0.051
12	+0.036	+0.038	+0.039	+0.041	+0.042	+0.044	+0.045
14	+0.032	+0.033	+0.035	+0.036	+0.037	+0.039	+0.040
16	+0.028	+0.029	+0.030	+0.031	+0.032	+0.033	+0.034
18	+0.023	+0.024	+0.025	+0.026	+0.027	+0.028	+0.029
20	+0.019	+0.020	+0.020	+0.021	+0.022	+0.023	+0.024
22	+0.014	+0.015	+0.016	+0.016	+0.017	+0.017	+0.018
24	+0.010	+0.011	+0.011	+0.011	+0.012	+0.012	+0.013
26	+0.006	+0.006	+0.006	+0.006	+0.007	+0.007	+0.007
28	+0.001	+0.001	+0.001	+0.002	+0.002	+0.002	+0.002
30	−0.003	−0.003	−0.003	−0.003	−0.003	−0.004	−0.004
32	−0.007	−0.008	−0.008	−0.008	−0.009	−0.009	−0.009
34	−0.012	−0.012	−0.013	−0.013	−0.014	−0.014	−0.015
36	−0.016	−0.017	−0.017	−0.018	−0.019	−0.019	−0.020
38	−0.020	−0.021	−0.022	−0.023	−0.024	−0.025	−0.026
40	−0.025	−0.026	−0.027	−0.028	−0.029	−0.030	−0.031
42	−0.029	−0.030	−0.032	−0.033	−0.034	−0.035	−0.036
44	−0.033	−0.035	−0.036	−0.038	−0.039	−0.040	−0.042
46	−0.038	−0.039	−0.041	−0.043	−0.044	−0.046	−0.047
48	−0.042	−0.044	−0.046	−0.047	−0.049	−0.051	−0.053
50	−0.046	−0.048	−0.050	−0.052	−0.054	−0.056	−0.058
52	−0.051	−0.053	−0.055	−0.057	−0.059	−0.061	−0.064
54	−0.055	−0.057	−0.060	−0.062	−0.064	−0.067	−0.069
56	−0.060	−0.062	−0.064	−0.067	−0.069	−0.072	−0.074
58	−0.064	−0.066	−0.069	−0.072	−0.074	−0.077	−0.080
60	−0.068	−0.071	−0.074	−0.077	−0.080	−0.082	−0.085
62	−0.073	−0.076	−0.079	−0.082	−0.085	−0.088	−0.091
64	−0.077	−0.080	−0.083	−0.086	−0.090	−0.093	−0.096
66	−0.081	−0.085	−0.088	−0.091	−0.095	−0.098	−0.101
68	−0.085	−0.089	−0.093	−0.096	−0.100	−0.103	−0.107
70	−0.090	−0.094	−0.097	−0.101	−0.105	−0.109	−0.112
72	−0.094	−0.098	−0.102	−0.106	−0.110	−0.114	−0.118
74	−0.098	−0.103	−0.107	−0.111	−0.115	−0.119	−0.123
76	−0.103	−0.107	−0.111	−0.116	−0.120	−0.124	−0.128
78	−0.107	−0.112	−0.116	−0.120	−0.125	−0.129	−0.134
80	−0.111	−0.116	−0.121	−0.125	−0.130	−0.135	−0.139
82	−0.116	−0.121	−0.125	−0.130	−0.135	−0.140	−0.145
84	−0.120	−0.125	−0.130	−0.135	−0.140	−0.145	−0.150
86	−0.124	−0.130	−0.135	−0.140	−0.145	−0.150	−0.155
88	−0.129	−0.134	−0.139	−0.145	−0.150	−0.155	−0.161
90	−0.133	−0.138	−0.144	−0.150	−0.155	−0.161	−0.166
92	−0.137	−0.143	−0.149	−0.154	−0.160	−0.166	−0.172
94	−0.142	−0.147	−0.155	−0.159	−0.165	−0.171	−0.177
96	−0.146	−0.152	−0.158	−0.164	−0.170	−0.176	−0.182
98	−0.150	−0.156	−0.163	−0.169	−0.175	−0.181	−0.188
100	−0.154	−0.161	−0.167	−0.174	−0.180	−0.187	−0.193

From table 44 of Smithsonian Meteorological Tables, 1939.

Example:

Observed height of barometer	=29.502
Attached thermometer, 68 degrees F.	
Reduction for temperature	= 0.105
Barometer reading corrected for temperature	=29.397

ATMOSPHERIC PRESSURE

This table is compiled from elevations and normal atmospheric pressures at United States Weather Bureau stations.

Elevation in feet	Inches mercury	Pounds absolute	Elevation in feet	Inches mercury	Pounds absolute
0	30.00	14.73	2000	27.90	13.70
100	29.89	14.68	2500	27.39	13.45
200	29.78	14.63	3000	26.90	13.21
300	29.67	14.57	3500	26.41	12.97
400	29.56	14.52	4000	25.93	12.74
500	29.45	14.46	4500	25.46	12.50
600	29.34	14.41	5000	25.00	12.28
800	29.13	14.31	5500	24.54	12.05
1000	28.93	14.21	6000	24.10	11.84
1500	28.41	13.95	6500	23.67	11.63

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ALTITUDE AND ATMOSPHERIC PRESSURE

This table from the United States Weather Bureau gives altitudes and average atmospheric pressures.

Location	Elevation in feet above sea level	Average atmospheric pressure pounds	Location	Elevation in feet above sea level	Average atmospheric pressure pounds
Abilene, Tex.	1738	13.85	Hartford, Conn.	159	14.66
Albany, N. Y.	97	14.70	Helena, Mont.	4110	12.67
Amarillo, Tex.	3676	12.90	Houston, Tex.	138	14.68
Asheville, N. C.	2253	13.62	Indianapolis, Ind.	822	14.32
Altanta, Ga.	1173	14.16	Kansas City, Mo.	963	14.23
Atlantic City, N. J.	52	14.72	Keokuk, Iowa	614	14.42
Austin, Tex.	605	14.43	Knoxville, Tenn.	995	14.25
Baker, Ore.	3471	13.01	Lander, Wyo.	5372	12.10
Baltimore, Md.	123	14.69	Lincoln, Neb.	1189	14.11
Binghamton, N. Y.	871	14.29	Los Angeles, Cal.	338	14.55
Birmingham, Ala.	700	14.39	Louisville, Ky.	525	14.48
Bismarck, N. Dak.	1674	13.84	Madison, Wis.	974	14.23
Boise, Idaho	2739	13.35	Memphis, Tenn.	399	14.55
Boston, Mass.	125	14.67	Miami, Fla.	25	14.74
Brownsville, Tex.	57	14.69	Milwaukee, Wis.	681	14.38
Buffalo, N. Y.	767	14.33	Minneapolis, Minn.	918	14.23
Burlington, Vt.	403	14.51	Montgomery, Ala.	223	14.65
Cairo, Ill.	358	14.57	Nashville, Tenn.	546	14.48
Charleston, S. C.	48	14.74	New Orleans, La.	53	14.73
Charlotte, N. C.	779	14.36	New York, N. Y.	314	14.58
Chattanooga, Tenn.	762	14.37	North Platte, Neb.	2821	13.29
Cheyenne, Wyo.	6088	11.79	Oklahoma City, Okla.	1214	14.11
Chicago, Ill.	673	14.39	Omaha, Neb.	1105	14.16
Cincinnati, Ohio	627	14.43	Parkesburg, W. Va.	637	14.45
Cleveland, Ohio	762	14.34	Philadelphia, Pa.	114	14.70
Columbia, N. C.	784	14.34	Pittsburgh, Pa.	842	14.31
Columbus, Ohio	822	14.33	Pocatello, Idaho	4477	12.52
Concord, N. H.	289	14.57	Pueblo, Colo.	4685	12.42
Corpus Christi, Tex.	20	14.72	Rapid City, S. Dak.	3259	13.06
Dallas, Tex.	512	14.47	Reno, Neb.	4532	12.51
Dayton, Ohio	899	14.29	Rochester, N. Y.	523	14.46
Del Rio, Tex.	944	14.22	Roswell, N. Mex.	3566	12.95
Denver, Colo.	5292	12.14	Sacramento, Cal.	69	14.69
Des Moines, Iowa	861	14.29	St. Louis, Mo.	568	14.45
Detroit, Mich.	730	14.36	St. Paul, Minn.	837	14.28
Dodge City, Kan.	2509	13.46	Salt Lake City, Utah	4360	12.59
Dubuque, Iowa	700	14.37	San Antonio, Tex.	693	14.38
Duluth, Minn.	1133	14.12	San Diego, Cal.	87	14.68
Elkins, W. Va.	1947	13.77	San Francisco, Cal.	155	14.66
El Paso, Tex.	3778	12.86	Santa Fe, N. Mex.	7013	11.44
Erie, Pa.	714	14.37	Seattle, Wash.	125	14.69
Evansville, Ind.	431	14.53	Shreveport, La.	249	14.62
Fort Smith, Ark.	457	14.50	Spokane, Wash.	1929	13.74
Fort Wayne, Ind.	856	14.29	Syracuse, N. Y.	597	14.43
Fort Worth, Tex.	670	14.39	Toledo, Ohio	628	14.42
Grand Rapids, Mich.	707	14.37	Washington, D. C.	112	14.70
Harrisburg, Pa.	374	14.55	Yuma, Ariz.	141	14.61

MERCURY VACUUM—ABSOLUTE PRESSURE

Based on atmospheric pressure of 14.4 pounds and mercury at 32 degrees F.

Inches mercury vacuum	Inches mercury absolute	Pounds per square inch absolute	Inches mercury vacuum	Inches mercury absolute	Pounds per square inch absolute
1	28.32	13.91	16	13.32	6.54
2	27.32	13.42	17	12.32	6.05
3	26.32	12.93	18	11.32	5.56
4	25.32	12.44	19	10.32	5.07
5	24.32	11.94	20	9.32	4.58
6	23.32	11.45	21	8.32	4.09
7	22.32	10.96	22	7.32	3.59
8	21.32	10.47	23	6.32	3.10
9	20.32	9.98	24	5.32	2.61
10	19.32	9.49	25	4.32	2.12
11	18.32	9.00	26	3.32	1.63
12	17.32	8.51	27	2.32	1.14
13	16.32	8.01	28	1.32	0.65
14	15.32	7.52	29	0.32	0.16
15	14.32	7.03	30	.....	.....

REPORT OF COMMITTEE ON NATURAL GAS RESERVES
AMERICAN GAS ASSOCIATION

The summary of proved recoverable reserves of natural gas and natural gas liquids of the United States, as of December 31, 1951, is as follows:

NATURAL GAS RESERVES
(Millions of cubic feet)

Total proved reserves as of December 31, 1950		185,592,699
Extensions and revisions of previous estimate	13,013,606	
New reserves discovered in 1951	3,039,385	
Net changes in "stored gas" during 1951	132,751	
Total proved reserves added and net changes in "stored gas" during 1951		16,185,742
Total proved reserves as of December 31, 1950 and additions during 1951		201,778,441
Deduct production during 1951		7,966,941
Total proved reserves of natural gas as of December 31, 1951		193,811,500

Reserves data are shown by states in Table 1.

NATURAL GAS LIQUIDS RESERVES
(Thousands of barrels of 42 U. S. Gallons)

Total proved reserves as of December 31, 1950		4,267,663
Extensions and revisions of previous estimate	648,497	
New reserves discovered in 1951	75,494	
Total proved reserves added in 1951		723,991
Total proved reserves as of December 31, 1950 and new proved reserves added in 1951		4,991,654
Deduct production during 1951		267,052
Total proved reserves of natural gas liquids as of December 31, 1951		4,724,602

SUMMARY OF ANNUAL ESTIMATES OF NATURAL GAS RESERVES

December 31, 1945 to December 31, 1951

(Millions of Cubic Feet—14.65 psia, at 60 deg F)

Year	Natural Gas Added during Year: Extensions and Revisions	Natural Gas Added during Year: Discoveries of New Fields and New Pools in Old Fields	Natural Gas Added during Year: Total of Discoveries, Revisions and Extensions	Net Change in Storage	Net Production during Year	Estimated Proved Reserves as of End of Year	Increase over Previous Year
1945	. . . .	. . . . .	. . . . .	. . . .	. . . . .	147,789,367	. . . . .
1946	*	*	17,729,152	*	4,942,617	160,575,901	12,786,535
1947	7,570,654	3,410,170	10,980,824	*	5,629,811	165,926,914	5,351,013
1948	9,769,483	4,129,089	13,898,572	51,482	6,007,628	173,869,340	7,942,426
1949	8,061,429	4,612,870	12,674,299	82,746	6,245,041	180,381,344	6,512,004
1950	9,172,381	2,877,351	12,049,732	54,301	6,892,678	185,592,699	5,211,355
1951	13,013,606	3,039,385	16,185,742	132,751	7,966,941	193,811,500	8,218,801

*Not estimated.

TOTAL GAS UTILITY SALES, BY TYPE OF GAS, 1932-1951

Note: Liquified petroleum gas data are included with manufactured gas prior to 1945. Excludes sales for resale.

(Millions of therms)

Year	Total	Type of Gas			
		Natural	Manufactured	Mixed	Liquified Petroleum
1932	10,441.3	8,190.0	1,731.1	520.2	
1933	10,530.6	8,373.8	1,579.8	577.0	
1934	12,063.4	9,831.6	1,609.9	621.9	
1935	12,923.9	10,635.1	1,610.5	678.3	
1936	14,692.9	12,356.1	1,594.2	742.6	
1937	15,773.4	13,480.0	1,535.2	758.2	
1938	14,681.6	12,422.8	1,525.8	733.0	
1939	15,926.8	13,576.2	1,580.4	770.2	
1940	17,235.4	14,681.4	1,688.1	865.9	
1941	19,009.3	16,358.3	1,725.6	925.4	
1942	20,848.7	17,970.1	1,848.4	1,030.2	
1943	23,414.7	20,324.6	1,967.1	1,123.0	
1944	25,119.8	21,941.0	2,034.9	1,143.9	
1945	25,867.7	22,562.8	2,087.5	1,194.2	23.2
1946	26,379.1	22,913.2	2,176.1	1,253.3	36.5
1947	29,882.4	26,021.5	2,319.2	1,481.4	60.3
1948	33,885.3	30,164.0	2,368.3	1,266.6	86.4
1949	35,789.7	32,233.9	2,274.0	1,190.9	90.9
1950	42,090.1	38,499.9	2,216.7	1,283.6	89.9
1951	48,221.8	44,718.3	1,763.0	1,652.4	88.1

TOTAL GAS UTILITY SALES, BY CLASS OF SERVICE, 1932-1951

Note: Excludes sales for resale.

(Millions of therms)

Year	Total	Residential	Commercial	Industrial	Other
1932	10,441.3	4,672.3	1,193.3	4,533.8	41.9
1933	10,530.6	4,237.2	1,150.3	5,113.8	29.3
1934	12,063.4	4,201.5	1,101.6	6,698.6	61.7
1935	12,923.9	4,444.5	1,211.1	7,220.9	47.4
1936	14,692.9	4,784.2	1,368.8	8,279.6	260.3
1937	15,773.4	4,987.3	1,381.5	9,041.1	363.5
1938	14,681.6	4,956.2	1,379.6	7,940.9	404.9
1939	15,926.8	5,289.4	1,468.5	8,768.3	400.6
1940	17,235.4	5,823.1	1,597.7	9,543.7	270.9
1941	19,009.3	5,862.0	1,649.5	11,206.0	291.8
1942	20,848.7	6,678.8	1,989.7	11,723.0	457.2
1943	23,414.7	7,001.4	2,083.1	13,582.4	747.8
1944	25,119.8	7,312.5	2,208.3	14,634.7	964.3
1945	25,867.7	7,749.3	2,497.3	14,523.3	1,097.8
1946	26,379.1	8,482.3	2,629.9	14,602.2	664.7
1947	29,882.4	10,086.5	3,106.7	15,791.8	897.4
1948	33,885.3	11,152.9	3,535.3	17,980.9	1,216.2
1949	35,790.4	11,827.9	3,724.4	18,978.5	1,259.6
1950	42,090.1	13,839.1	4,103.8	22,886.7	1,260.5
1951	48,221.8	16,204.5	4,559.4	25,521.9	1,936.0

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BELLAMY DEMAND-CHARGE RATE FORMULA
For All Load Factors

$$\text{Demand-charge per Mcf gas delivered} = \frac{3.288 \times DC}{LF}$$

where

DC = Demand-charge per Mcf of billing demand per month
LF = Load factor

Therefore,

$$\text{Price per Mcf of gas delivered} = \frac{3.288 \times DC}{LF} + \text{commodity charge}$$

Example:

(Assumed Gas Rate)
Demand charge = $2.10 per Mcf billing demand per month
Commodity charge = 21c per Mcf of gas delivered
To determine price of gas at 70 per cent load factor

Then

$$\text{Gas price per Mcf} = \frac{3.288 \times 210}{70} + 21 = 9.86 + 21 = 30.86c$$

SELECTED OPERATING STATISTICS OF MAJOR PIPE LINE SYSTEMS, 1951

Note: Includes pipe line systems with more than 500 miles of transmission mains and $5,000,000 operating revenues.

Name of Pipeline System	Compressor Facilities		Miles of Transmission Mains				Maximum Daily Capacity (MMCF)	1951 Operating Revenues (000,000)	Terminals
	No. of Stations	Installed Horsepower	Total	10" & Under Diameter	10.1–20.0" Diameter	20.1" & Over Diameter			
Atlantic Seaboard Corp.—Virginia Gas Transmission Corp.	6	23,945	739	54	425	260	384[a]	$18.1	Kanawha County, W. Va. & Pike County, Kentucky—Rockville, Md. & Pa.-Md. stateline in Cecil County, Md.
Canadian River Gas Co.—Colorado Interstate Gas Co.	10	59,035	886	210	438	238	405	18.2	Hugoton and Amarillo Fields—Denver
Cities Service Gas Co.	30	143,895	4,294	1,461	2,201	632	1,038[a]	39.3	Hugoton, Panhandle & Cement (Okla.) Fields—Kansas City, Springfield & St. Joseph, Mo.; Superior, Neb.
East Tennessee Natural Gas Co.	0	0	547	98	279	170	237	7.1	Lobelville & Greenbier Stations—Chattanooga & Knoxville, Tenn.
El Paso Natural Gas Co.	34	315,580	5,011	1,188	1,502	2,321	846	60.0	Scurry County (Tex.), Panhandle & San Juan Basin (N.M.) Fields—Yuma, Topock, Ariz.; Blythe, Calif.
Interstate Natural Gas Co.	2	20,100	766	106	411	249	447[a]	16.7	North Tepertate (La.) & Panhandle Fields—Baton Rouge, La.
Michigan-Wisconsin Pipeline Co.	16	156,890	1,568	346	64	1,158	703[a]	27.2	Hugoton Field—Milwaukee & Madison, Wis.; Austin Storage Field, Mich.
Mississippi River Fuel Co.	20	101,205	1,270	245	115	910	442[a]	29.8	Monroe Field—St. Louis, Mo.; Alton, Ill.
Natural Gas Pipeline Co.—Chicago District Pipeline Co.	22	157,555	2,375	107	334	1,934	559[a]	41.9	Hugoton & Panhandle Fields—Chicago
New York State Natural Gas Corp.	7	32,380	1,040	138	902	0	442[a]	24.5	Brave, Pa. & Pa.-Ohio border—Albany, Caledonia, Auburn, N. Y.
Northern Natural Gas Co.	25	229,920	4,471	1,437	1,418	1,616	675	34.8	Hugoton & Panhandle Fields—Minneapolis, St. Paul, Minn., Sioux Falls, S. D.
Panhandle Eastern Pipeline Co.	18	260,420	4,758	854	1,020	2,884	934[a]	$50.7	Hugoton & Panhandle Fields—Detroit, Kalamazoo, Saginaw, Mich.
Southern Natural Gas Co.	17	123,505	2,751	638	1,461	652	627	35.5	Logansport, Monroe & Gwinville (Miss.) Fields—Columbus, Macon, Milledgville, Ga.
Tennessee Gas Transmission Co.	20	374,520	5,477	203	786	4,488	1,200	75.7	San Salvador and Carthage (Tex.) Fields—Cornwell Stat., W. Va.; Buffalo, N. Y. & N. Y.-Mass. Border
Texas Eastern Transmission Corp.	26	277,650	3,442	99	1,887	1,456	740	84.1	Oakford Storage Field, Longview & Houston, Tex.—Philadelphia & New York
Texas Gas Transmission Co.	18	112,340	2,516	839	789	888	710	39.5	Carthage & North Tepertate Field, La.—Bowling Green, Ky.; Terre Haute, Ind.; Middletown, Ohio
Texas Illinois Natural Gas Pipeline Co.	5	50,000	1,421	0	175	1,246	384	1.8	La Gloria Field (Tex.)—Volo, Ill.
Transcontinental Gas Pipeline Corp.	19	233,950	2,329	344	224	1,761	528[a]	43.2	Lacy Field (Tex.)—New York City
Trunkline Gas Supply Co.	4	32,000	1,209	0	264	945	270[a]	4.6	McAllen Field (Tex.)—Tuscola, Ill.
United Gas Pipeline Co.	35	77,351	7,359	3,289[b]	3,553[b]	517[b]	3,081[a]	74.4	Laredo, Austin, Ft. Worth, New Orleans, Pensacola; Monroe & Panhandle Fields—Wichita Falls, Tex.

a. Maximum daily sendout, 1951.
b. Estimated.

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DAILY CAPACITY OF GAS WELLS[1]

Open flow in cubic feet in 24 hours based on the following conditions: base and flowing temperature, 60 degrees F., base pressure, 14.65 pounds absolute (four ounces), specific gravity, 0.60.

Pressure by[2]			Diameter of opening—inches							
Water gage	Mercury gage	Pressure gage	1	2	3	4	5-5 3/16	6 1/4	6 5/8	8 1/4
Ins.	Ins.	PSI								
.1	...	...	12,000	48,000	108,000	192,000	300,000	453,600	507,000	783,360
.2	...	...	16,848	67,392	151,632	269,568	421,200	636,854	711,828	1,099,772
.3	...	...	20,760	83,040	186,840	332,160	519,000	784,728	877,110	1,355,212
.4	...	...	23,640	94,560	212,760	378,240	591,000	893,592	998,790	1,543,219
.5	...	...	26,448	105,792	238,032	423,168	661,200	999,734	1,117,428	1,726,525
.6	...	...	28,992	115,968	260,928	463,872	724,800	1,095,897	1,224,912	1,892,597
.7	...	...	31,560	126,240	284,040	504,960	789,000	1,192,968	1,331,850	2,062,368
.8	...	...	33,600	134,400	302,400	537,600	840,000	1,270,080	1,419,600	2,193,408
.9	...	...	35,760	143,040	321,840	572,160	894,000	1,351,728	1,510,860	2,334,412
1.	...	...	37,680	150,720	339,120	602,880	942,000	1,424,304	1,591,980	2,459,750
1.25	...	...	42,240	168,960	380,160	675,840	1,056,000	1,596,672	1,784,640	2,757,427
1.34	.1	...	44,040	176,160	396,360	704,640	1,101,000	1,664,712	1,860,690	2,874,931
1.5	.11	...	46,080	184,320	414,720	737,280	1,152,000	1,741,824	1,946,880	3,008,102
1.75	.13	...	49,800	199,200	448,200	796,800	1,245,000	1,882,440	2,104,050	3,250,944
2.	.15	...	53,280	213,120	479,520	852,480	1,332,000	2,013,984	2,251,080	3,478,118
2.5	.18	...	59,520	238,080	535,680	952,320	1,488,000	2,249,856	2,514,720	3,885,465
2.69	.2	...	62,160	248,640	559,440	994,560	1,554,000	2,349,648	2,626,260	4,057,804
3.	.22	...	65,160	260,640	586,440	1,042,560	1,629,000	2,463,048	2,753,010	4,253,644
3.5	.26	...	70,392	281,568	633,528	1,126,272	1,759,800	2,660,817	2,974,062	4,595,189
4.04	.3	...	76,080	304,320	684,720	1,217,280	1,902,000	2,875,824	3,214,380	4,966,502
4.5	.33	...	79,920	319,680	719,280	1,278,720	1,998,000	3,020,976	3,376,620	5,217,177
5.	.37	...	82,680	330,720	744,120	1,322,880	2,067,000	3,125,304	3,493,230	5,397,350
5.39	.4	...	87,720	350,880	789,480	1,403,520	2,193,000	3,315,816	3,706,170	5,726,361
6.	.44	...	92,160	368,640	829,440	1,474,560	2,304,000	3,483,648	3,893,760	6,016,204
6.74	.5	...	98,280	393,120	884,520	1,572,480	2,457,000	3,714,984	4,152,330	6,415,718
8.08	.6	...	107,760	431,040	969,840	1,724,160	2,694,000	4,073,328	4,552,860	7,034,572
9.	.66	...	113,040	452,160	1,017,360	1,808,640	2,826,000	4,272,912	4,770,940	7,379,251
9.43	.7	...	116,400	465,600	1,047,600	1,862,400	2,910,000	4,399,920	4,817,900	7,598,592
10.	.74	...	119,040	476,160	1,071,360	1,904,640	2,976,000	4,499,712	5,029,440	7,770,931
10.78	.8	...	124,320	497,280	1,118,880	1,989,120	3,108,000	4,699,296	5,252,520	8,115,609
12.	.88	...	130,320	521,280	1,172,880	2,085,120	3,258,000	4,926,096	5,516,020	8,507,289
12.13	.9	...	131,880	527,520	1,186,920	2,110,080	3,297,000	4,985,064	5,571,930	8,609,126
13.75	1.02	.50	138,600	554,400	1,247,400	2,217,600	3,465,000	5,239,080	5,856,850	9,047,808
20.22	1.5	.73	170,280	681,120	1,532,520	2,724,480	4,257,000	6,436,584	7,194,330	11,115,875
26.96	2.	.98	196,680	786,720	1,770,120	3,146,880	4,917,000	7,434,504	8,309,730	12,839,270
33.70	2.5	1.22	219,960	879,840	1,979,640	3,519,360	5,499,000	8,314,488	9,293,310	14,358,988
40.44	3.	1.47	240,720	962,880	2,166,480	3,851,520	6,018,000	9,099,216	10,170,420	15,714,201
47.18	3.5	1.71	259,920	1,039,680	2,339,280	4,158,720	6,498,000	9,824,970	10,981,620	16,967,577
53.92	4.	1.96	277,200	1,108,800	2,494,800	4,435,200	6,930,000	10,478,160	11,711,700	18,095,616
60.66	4.5	2.20	294,600	1,178,650	2,651,760	4,714,240	7,366,000	11,135,880	12,448,530	19,231,488
67.40	5.	2.45	310,800	1,243,200	2,797,200	4,972,800	7,770,000	11,748,240	13,131,300	20,289,024
74.14	5.5	2.69	325,800	1,303,200	2,932,200	5,212,800	8,145,000	12,315,240	13,765,050	21,268,224
80.88	6.	2.94	340,200	1,360,800	3,061,800	5,443,200	8,505,000	12,859,560	14,373,450	22,208,256
87.62	6.5	3.18	354,200	1,416,480	3,187,080	5,665,920	8,853,000	13,385,736	14,961,570	23,116,953
94.36	7.	3.43	367,680	1,470,720	3,309,120	5,882,880	9,192,000	13,898,304	15,533,480	24,002,150

80.88	6.	2.94	340,200	1,416,480	3,187,080	5,665,920	8,853,000	13,898,304	15,533,480	24,002,150
87.62	6.5	3.18	354,200	1,416,480	3,309,120	5,882,880	9,192,000			
94.36	7.	3.43	367,680	1,470,720						

DAILY CAPACITY OF GAS WELLS—Continued

Pressure by[2]			Diameter of opening—inches							
Water gage	Mercury gage	Pressure gage	1	2	3	4	5-5 3/16	6¼	6⅝	8¼
Ins.	Ins.	PSI								
101.10	7.5	3.67	380,400	1,521,600	3,423,600	6,086,400	9,510,000	14,379,120	16,071,900	24,832,512
107.84	8.	3.92	392,880	1,571,520	3,535,920	6,286,080	9,822,000	14,850,864	16,599,180	25,647,206
114.58	8.5	4.16	405,000	1,620,000	3,645,000	6,480,000	10,125,000	15,309,000	17,111,250	26,438,400
121.32	9.	4.41	416,640	1,666,650	3,749,760	6,666,240	10,416,000	15,748,992	17,603,040	27,198,259
128.06	9.5	4.61	428,280	1,713,120	3,854,520	6,852,480	10,707,000	16,188,984	18,095,460	27,958,118
134.80	10.	4.90	439,920	1,759,680	3,959,280	7,038,720	10,998,000	16,604,784	18,586,620	28,717,977
164.46	12.2	6.	476,040	1,904,150	4,284,360	7,616,640	11,901,000	17,994,312	20,112,690	31,075,891
.....	14.23	7.	517,320	2,069,280	4,665,880	8,277,120	12,933,000	19,554,696	21,856,770	33,770,649
.....	16.26	8.	542,400	2,169,600	4,881,600	8,678,400	13,560,000	20,502,720	22,916,400	35,407,872
.....	18.30	9.	569,640	2,278,560	5,126,760	9,114,240	14,241,000	21,532,392	24,067,290	37,186,099
.....	20.33	10.	595,440	2,381,760	5,358,960	9,527,040	14,886,000	22,507,632	25,157,340	38,870,032
.....	22.36	11.	621,960	2,487,840	5,597,640	9,951,360	15,549,000	23,510,088	26,277,810	40,601,548
.....	24.39	12.	642,600	2,570,400	5,783,400	10,281,600	16,065,000	24,290,280	27,149,850	41,948,928
.....	26.43	13.	664,680	2,658,720	5,982,120	10,634,880	16,617,000	25,124,904	27,933,177	43,390,310
.....	28.46	14.	683,880	2,735,520	6,154,920	10,942,080	17,097,000	25,850,664	28,893,930	44,643,686
.....	30.50	15.	704,520	2,818,080	6,340,680	11,272,320	17,613,000	26,630,856	29,765,970	45,991,065
.....	32.53	16.	720,720	2,882,880	6,486,480	11,531,520	18,018,000	27,243,216	30,460,430	47,048,601
.....	36.60	18.	750,240	3,000,960	6,752,160	12,003,840	18,756,000	28,359,072	31,697,640	48,975,667
.....	40.66	20.	785,520	3,142,080	7,069,680	12,568,320	19,638,000	29,692,656	33,188,220	51,278,745
.....	44.73	22.	803,280	3,213,120	7,229,520	12,852,480	20,082,000	30,363,984	33,938,580	52,437,676
.....	50.81	25.	854,880	3,419,520	7,693,920	13,678,080	21,372,000	32,314,464	36,718,680	55,806,124
.....	61.00	30.	910,920	3,643,680	8,198,280	14,574,720	22,773,000	34,432,776	38,486,370	59,464,415
.....	71.16	35.	960,960	3,843,840	8,648,640	15,375,360	24,024,000	36,324,288	40,600,560	62,731,027
.....	81.33	40.	1,006,680	4,026,720	9,060,120	16,106,880	25,167,000	38,052,504	42,532,230	65,715,628
.....	91.50	45.	1,046,520	4,186,080	9,418,680	16,774,320	26,163,000	39,558,456	44,215,470	68,316,383
.....	....	50.	1,081,920	4,327,680	9,737,280	17,310,720	27,048,000	40,896,576	45,711,120	70,627,295
.....	....	60.	1,137,120	4,548,480	10,234,080	18,193,920	28,428,000	42,983,136	48,043,320	74,230,751
.....	....	75.	1,223,400	4,893,600	11,010,600	19,574,400	30,585,000	46,244,450	51,688,650	79,863,110
.....	....	90.	1,304,400	5,217,600	11,739,600	20,870,400	32,610,000	49,306,320	55,110,900	85,150,790
.....	....	100.	1,336,920	5,347,680	12,032,280	21,390,720	33,422,000	50,535,576	56,484,860	87,273,695
.....	....	110.	1,369,320	5,477,280	12,323,880	21,909,120	34,233,000	51,760,296	57,853,770	89,388,767
.....	....	120.	1,401,720	5,606,880	12,615,480	22,427,520	35,043,000	52,985,016	59,222,670	91,504,281

[1]Courtesy—Dresser Manufacturing Company.

[2]Pressure as measured with a Pitot tube inserted in the flowing gas just inside the pipe or tubing, between one-third and one-fourth of the pipe diameter from the outer edge, and with the plane of the opening in the tube held at right angles to the flowing gas. The top length of tubing or casing should be free from fittings for a distance of 10 feet below the mouth of the well when the test is made. The test should not be made in a collar or gate or at the mouth of any fitting. The well should be blown off for at least 3 hours prior to final reading, or until the readings do not decrease over a 15-minute period.

If the specific gravity of the gas is other than 0.60, multiply the flow by the square root of 0.60, divided by the specific gravity of the gas from the well being tested. For flowing temperatures above or below 60 degrees F., deduct or add 1 per cent for each 10 degrees, respectively.

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GAS FLOW FORMULAS

HIGH PRESSURE GAS FLOW

The Weymouth Formula. This is considered to be the best known and most widely used formula. The original formula is as follows:

$$Q = 433.5 \frac{T_o}{P_o} \left[\frac{(P_1^2 - P_2^2) d^{16/3}}{GTL} \right]^{1/2}$$

where

Q = flow cubic feet per day under standard conditions (P_o and T_o)
d = internal diameter of pipe, inches
T_o = standard absolute temperature °F
T = temperature of flowing gas—absolute °F
P_o = standard pressure, psia
P_1 = initial pressure, psia
P_2 = terminal pressure, psia
G = specific gravity of gas, air = 1.0
L = length of pipe line, miles

By assuming

$T_o = 60 + 460 = 520°$ F
$P_o = 14.73$ psia
$T = 50 + 460 = 510°$ F

the above formula is simplified to:

$$Q = 676.2 \sqrt{\frac{(P_1^2 - P_2^2)\, d^{16/3}}{GL}}$$

or

$$Q = 676.2\, d^{8/3} \sqrt{\frac{P_1^2 - P_2^2}{GL}}$$

The Weymouth formula with supercompressibility. When the Weymouth Formula for Flow of Gas in Pipe Lines was introduced before the A. S. M. E. in 1912, the maximum working pressures in pipe lines did not exceed 350 to 400 pounds per square inch and the effects of the deviation of actual gases from the ideal gas laws were not thought to be significant and were not recognized.

With the much higher pressures that have been adopted since that time it is necessary to incorporate into the original formula an allowance for supercompressibility of gases to make it applicable to present practice. This adjustment is rendered relatively simple by taking advantage of the fact that within the pressure range for which gas transmission lines are now designed, and at the average temperature of flowing gas usually encountered in practice, natural gas follows a deviation pattern which may be represented by a straight line supercompressibility function of the pressure of the form of $(1 + JP) = \frac{1}{Z}$. By utilizing this relationship, the modified General Formula becomes:

$$Q = 433.5 \frac{T_o}{P_o} \left[\frac{(P_1^2 - P_2^2) d^{5\,1/3}}{GTL} \right]^{1/2} (1 + JP_m)^{1/2} \qquad (1)$$

and since

$$P_m = 2/3 \left[P_1 + P_2 - \frac{P_1 P_2}{P_1 + P_2} \right]$$

this reduces to

$$Q = 433.5 \frac{T_o}{P_o} \frac{d^{8/3}}{\sqrt{GTL}} [P_1^2 (1 + 2/3\, JP_1) - P_2^2 (1 + 2/3\, JP_2)]^{1/2} \qquad (2)$$

In the above,

P_m = Mean pressure of line, psia
J = Factor for supercompressibility.
Z = Reciprocal of $(1 + JP)$
r = Ratio of compressions = $\frac{P_1}{P_2}$

A simplified working formula applicable to general design problems can be derived from the general formula by assuming values for T_o, P_o, G and T which will approximate those to be anticipated in most cases and combining them into a constant, K, thus,

$$K = 433.5 \frac{T_o}{P_o \sqrt{GT}}.$$

The factor J may also be assumed at a constant value that will apply to the majority of cases without serious error.

By using the following values:

$T_o = 60 + 460 = 520$ deg. F
$P_o = 14.73$ psia (30" Hg.)
G = 0.65
$T = 50 + 460 = 510$ deg. F
J = 0.00022 per 1 psia

the value of K will be 840.5 and the working formula will be

$$Q = 840.5 \frac{d^{8/3}}{\sqrt{L}} [P_1^2 (1 + 0.000147\, P_1) - P_2^2 (1 + 0.000147\, P_2)]^{1/2} \quad (3)$$

For conditions other than those assumed above, K can be modified by multiplying by such of the following factors as is appropriate:

$$\frac{T_o}{520};\quad \frac{14.73}{P_o};\quad \sqrt{\frac{0.65}{G}};\quad \sqrt{\frac{510}{T}}.$$

If P_1 and P_2 are known, the simplest form of the formula in solving for Q, d or L is found by utilizing the ratio of compressions, $r = \frac{P_1}{P_2}$, thus:

$$Q = K \frac{d^{8/3}}{\sqrt{L}} P_2 [(r^2 - 1) + 2/3\, JP_2 (r^3 - 1)]^{1/2} \qquad (4)$$

The simplest method of solving for P_1 or P_2 is as follows:

1st. From equation (2) or (3), solve for the value of the parenthetical term under the radical which contains the unknown pressure, $P^2 (1 + 2/3\, JP)$. Call this C.

2nd. Select a trial pressure, P_a, preferably the round figure value nearest to the square root of C.

3rd. Solve for $C_a = P_a^2 (1 + 2/3\, JP_a)$.

4th. Select a second trial pressure, P_b, preferably a round figure nearest to the square root of .8C to .85C, and solve for $C_b = P_b^2 (1 + 2/3\, JP_b)$.

5th. Solve for the unknown P from

$$P = P_b + \frac{C - C_b}{C_a - C_b} (P_a - P_b)$$

being sure to do it algebraically, in case the selection of P_b should make C_b greater than C.

These computations are easily and quickly made on the slide rule with sufficient accuracy to satisfy most design problems encountered in practice, and within the range of precision fixed by other factors involved.

A line composed of several lengths L_1, L_2, etc., of diameters d_1, d_2, etc., can be transformed into a single equivalent line of uniform diameter d_o, by determining the equivalent length of each individual section by means of the formula $L_{o\,1} = L_1 \left(\frac{d_o}{d_1} \right)^{5\,1/3}$ and adding these equivalent section lengths together to form an equivalent line of diameter d_o and total length L_o.

To transform a length of pipe of diameter d and length L, to a pipe of equivalent capacity having a length L_o, the diameter of the equivalent section will be $d_o = d \left(\frac{L_o}{L} \right)^{3/16}$.

The diameter of a single pipe having a capacity equivalent to the aggregate capacity of several parallel, or looped lines of a common length and of diameters d_1, d_2, etc., is equal to

$$d_o = [d_1^{8/3} + d_2^{8/3} + \text{— etc.,}]^{3/8} = [\Sigma\, d^{8/3}]^{3/8}.$$

If the several loops have different lengths, the actual diameters of the loops must first be transformed into equivalent diameters of pipe having a common length, and these equivalent diameters then be added in accordance with the formula just given.

For general office use the formula can be still further simplified by combining the K and d factors into a single constant, $A = Kd^{8/3}$, and using a table of values of A for the principal sizes and weights of pipe in common use. Table 1 gives values of A for the constants assumed above and for pipes up to and including 30 inches outside diameter. Equation (3) then becomes:

$$Q = \frac{A}{\sqrt{L}}[P_1^2 (1 + 0.000147 P_1) - P_2^2 (1 + 0.000147 P_2)]^{1/2} \quad (5)$$

TABLE NO. 1

"A" FACTORS

Size (Inches)		Wall Thickness (Inches)	Internal Diameter (Inches)	"A"
1	(Nominal)	.133	1.049	954.6
1½	"	.145	1.610	2,992.
2	"	.154	2.067	5,826.
3	"	.216	3.068	16,700.
4	"	.237	4.026	34,470.
5-3/16	"	.304	4.892	57,950.
6	"	.280	6.065	102,800.
6⅝	"	.275	6.450	121,100.
8	"	.322	7.981	213,800.
8	"	.277	8.071	220,200.
8⅝	(O.D.)	.250	8.125	224,200.
10	(I.D.)	.365	10.020	392,100.
10¾	(O.D.)	.3125	10.125	403,200.
10¾	(O.D.)	.250	10.250	415,200.
12	"	.375	11.250	534,000.
12	"	.250	11.500	566,200.
12¾	"	.375	12.000	634,200.
12¾	"	.3125	12.125	652,000.
12¾	"	.250	12.250	670,100.
14	"	.375	13.250	826,000.
14	"	.3125	13.375	847,000.
14	"	.250	13.500	868,300.
16	"	.375	15.250	1,202,000.
16	"	.3125	15.375	1,224,000.
16	"	.250	15.500	1,255,000.
18	"	.375	17.250	1,669,000.
18	"	.3125	17.375	1,701,000.
18	"	.250	17.500	1,735,000.
20	"	.375	19.250	2,237,000.
20	"	.3125	19.375	2,275,000.
20	"	.250	19.500	2,314,000.
22	"	.375	21.250	2,911,000.
22	"	.3125	21.375	2,957,000.
24	"	.375	23.250	3,700,000.
24	"	.3125	23.375	3,753,000.
26	"	.375	25.250	4,611,000.
26	"	.3125	25.375	4,672,000.
28	"	.375	27.250	5,650,000.
28	"	.3125	27.375	5,720,000.
30	"	.375	29.250	6,825,000.
30	"	.3125	29.375	6,903,000.

FORMULA FOR DETERMINING MEAN PRESSURE (P_M) IN PIPE LINE

$$P_M = \tfrac{2}{3}\left(P_1 + P_2 - \frac{P_1 P_2}{P_1 + P_2}\right)$$

Values of $(d)^{5/3}$ and $(d)^{16/3}$

(Note — $d^{8/3} = \sqrt{d^{16/3}}$)

Diameter (d), inches			
External	Internal	$(d)^{8/3}$	$(d)^{16/3}$
2.375	2.067	6.933	48.063
3.500	3.068	19.87	394.99
4.500	4.026	41.02	1,682.6
6.625	6.040	121.0	14,640
6.625	6.125	125.6	15,773
6.625	6.250	132.5	17,567
8.625	8.071	262.1	68.700
8.625	8.125	266.8	71,182
8.625	8.185	272.1	74,035
10.000	9.625	419.2	175,710
10.750	10.192	488.3	238,440
10.750	10.250	495.7	245,760
12.750	12.090	770.0	592,870
12.750	12.188	786.7	618,920
12.750	12.250	797.5	635,930
14.000	13.500	1033.3	1,067,600
15.000	14.500	1250.2	1,563,000
16.000	15.250	1430.2	2,045,400
16.000	15.375	1461.7	2,136,500
16.000	15.500	1493.5	2,230,600
18.000	17.250	1986.6	3,946,500
18.000	17.375	2025.3	4,101,600
18.000	17.500	2064.3	4,261,400
20.000	19.250	2661.6	7,084,200
20.000	19.375	2707.9	7,333,000
20.000	19.432	2729.3	7,449,200
22.000	21.125	3410.4	11,631,000
22.000	21.375	3519.1	12,384,000
22.000	21.500	3574.1	12,775,000
24.000	23.125	4340.8	18,843,000
24.000	23.375	4466.8	19,953,000
24.000	23.500	4531.0	20,529,000
26.000	25.125	5415.4	29,326,000
26.000	25.500	5633.4	31,736,000
28.000	27.125	6642.3	44,120,000
28.000	27.500	6889.8	47,471,000
30.000	29.125	8030.0	64,482,000
30.000	29.500	8308.3	69,030,000

PANHANDLE FORMULA

This formula is used by many companies for the calculation of gas flow in large diameter (twelve inch and larger) transmission lines.

BASIC PANHANDLE FORMULA

$$Q = 435.87e\left(\frac{T_o}{P_o}\right)^{1.07881}\left(\frac{(P_1^2 - P_2^2)}{G^{0.8539}T_f L}\right)^{0.5394} d^{2.6182}$$

Substituting:

T_o = Base temperature = 60° + 460° = 520° abs
P_o = Base pressure = 14.73 psia
T_f = Flowing temperature = 50° + 460° = 510° abs
G = Gravity of gas = 0.686 (Panhandle gas)

and where:

P_1 = Initial pressure—psia
P_2 = Final pressure—psia
L = Length of line in miles
d = Diameter of pipe in inches
e = Experience factor

the equation can be resolved to:

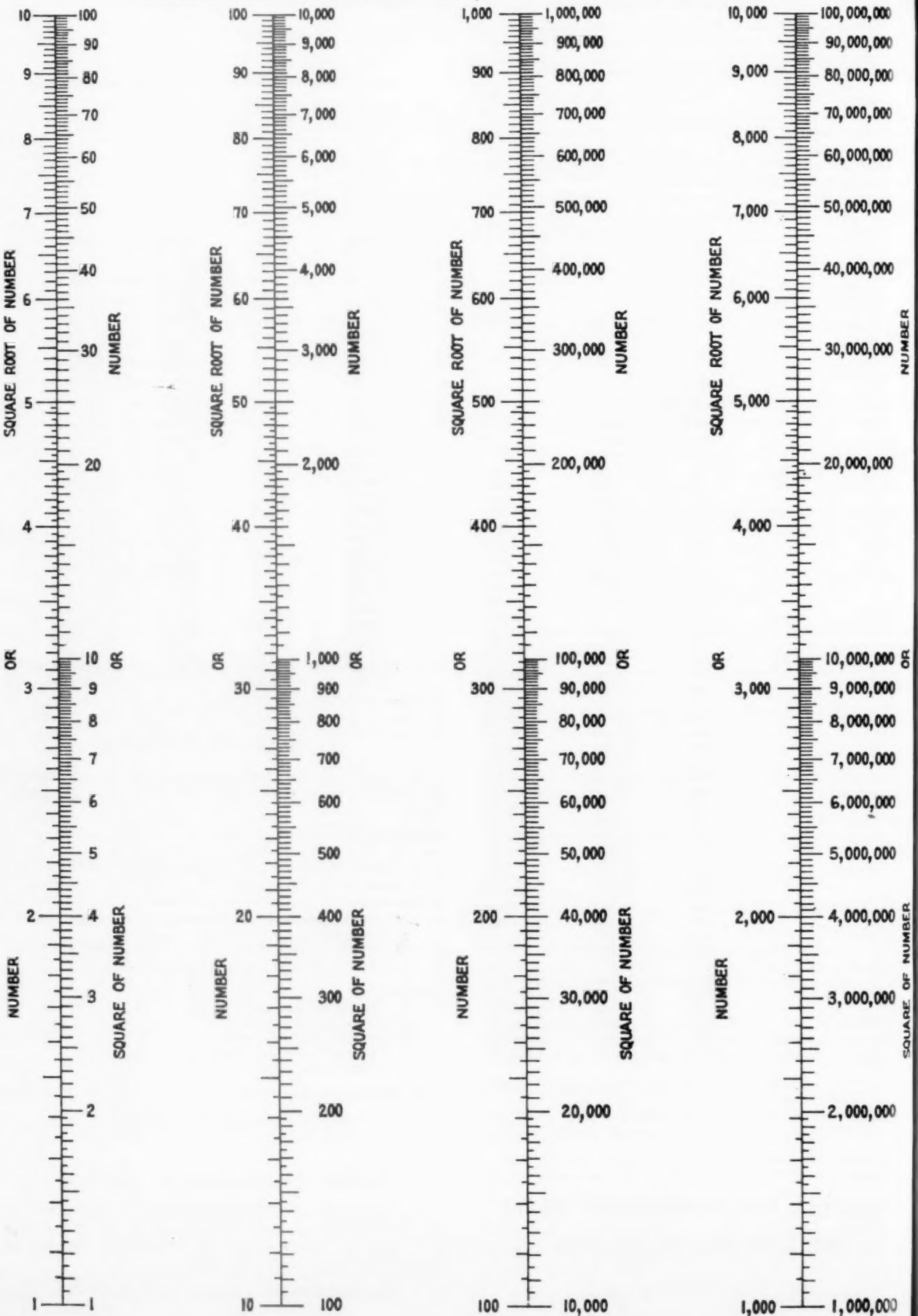
$$Q/d^{2.6182} = 839.51e\left(\frac{(P_1^2 - P_2^2)}{L}\right)^{0.5394}$$

SUPERCOMPRESSIBILITY FACTOR

If a flow formula, which does not reflect the deviation from the ideal gas law, is used for problems involving pressures above 200 lbs., its results may be corrected by applying the following supercompressibility factor

$$\text{Supercompressibility Factor} = \sqrt{1 + .0002P_M}$$

CONVERSION CHART FOR DETERMINING SQUARES AND SQUARE ROOTS OF NUMBERS



LOW PRESSURE GAS FLOW

For distribution system problems the Spitzglass formulas are:

FOR PRESSURES NOT EXCEEDING ONE POUND GAUGE:

$$Q = 3550\,K\left(\frac{h}{SL}\right)^{\frac{1}{2}}$$

Where:

Q = Flow per hour in cubic feet of gas at 14.73 psi absolute (30" Hg.) and 60° F.
H = Pressure drop in inches of water column.
S = Specific gravity of gas. Air = 1.0
L = Length of pipe in feet.
d = Internal diameter of pipe in inches.

$$K = \left(\frac{d^5}{1 + \frac{3.6}{d} + 0.03d}\right)^{\frac{1}{2}}$$

FOR PRESSURES EXCEEDING ONE POUND GAUGE:

$$Q = 4830\,K\left(\frac{Pa}{SL}\right)^{\frac{1}{2}}$$

Where:

Q = Flow per hour in cubic feet of gas at 14.73 psi absolute (30" Hg.) and 60° F.
P = Pressure drop between pipe terminals in pounds per square inch.
a = Average pressure in pipe line, pounds per square inch absolute. (Absolute initial pressure minus half the pressure drop.)
S = Specific gravity of gas. Air = 1.0
L = Length of pipe in feet.
d = Internal diameter of pipe in inches.

$$K = \left(\frac{d^5}{1 + \frac{3.6}{d} + 0.03d}\right)^{\frac{1}{2}}$$

Values of $\sqrt{d^5}$

Diameter (d) Inches (Internal)	$\sqrt{d^5}$
.75	.4871
.824 (¾" Pipe)	.6163
1.000	1.000
1.049 (1" Pipe)	1.127
1.38 (1¼" Pipe)	2.237
1.50	2.756
1.61 (1½" Pipe)	3.289
2.00	5.657
2.067 (2" Pipe)	6.143
2.469 (2½" Pipe)	9.579
3.00	15.59
3.068	16.49
4.00	32.00
4.026	32.52
6.00	88.18
8.00	181.0
10.00	316.2
12.00	498.8
16.00	1024.
20.00	1789.
24.00	2822.
30.00	4930.
36.00	7776.

EQUIVALENT LENGTHS OF PIPE FITTINGS AND VALVES

Listed below are the lengths (in feet) of standard pipe which produce the same pressure drop as the fitting named in the left hand column

Type of fitting or valve	Nominal pipe size in inches																		
	½	¾	1	1¼	1½	2	2½	3	4	6	8	10	12	14 O.D.	16 O.D.	18 O.D.	20 O.D.	24 O.D.	30 O.D.
Standard tee with entry or discharge through side	3.4	4.5	5.5	7.5	9.0	12	14	17	22	33	43	55	65	78	85	105	115	135	170
Standard elbow or run[a] of tee reduced ½[b]	1.7	2.2	2.7	3.7	4.3	5.5	6.5	8	12	16	20	26	31	36	42	47	52	64	80
Medium sweep elbow or run[a] of tee reduced ¼[b]	1.3	1.8	2.3	3.0	3.7	4.6	5.4	6.8	9.0	14	18	22	26	30	35	40	43	55	67
Long sweep elbow or run[a] of standard tee or butterfly valve	1	1.3	1.7	2.3	2.7	3.5	4.2	5.3	7	11	14	17	20	23	26	31	34	41	52
45° Elbow	.8	1.0	1.2	1.6	2.0	2.5	3.0	3.7	5.0	7.5	10	12	15	17	20	22	24	30	37
Close return bend	3.7	5.1	6.2	8.5	10	13	15	19	24	37	49	62	75	86	100	110	125	150	185
Globe valve, wide open	16	22	27	40	43	45	65	82	120	170	240	290	340	400	440	500	550	680	850
Angle valve, wide open	8.2	11	14	18	21	28	33	42	56	85	112	145	165	190	220	250	280	340	420
Swing check valve, wide open	4.0	5.2	6.6	9.0	11	14	16	19	26	39	52	66	78	92	106	120	130	145	160
Gate valve, wide open, or slight bushing reduction	0.4	0.5	0.6	0.8	0.9	1.2	1.3	1.7	2.3	3.5	4.5	5.7	6.7	8.0	9.0	11	12	14	17

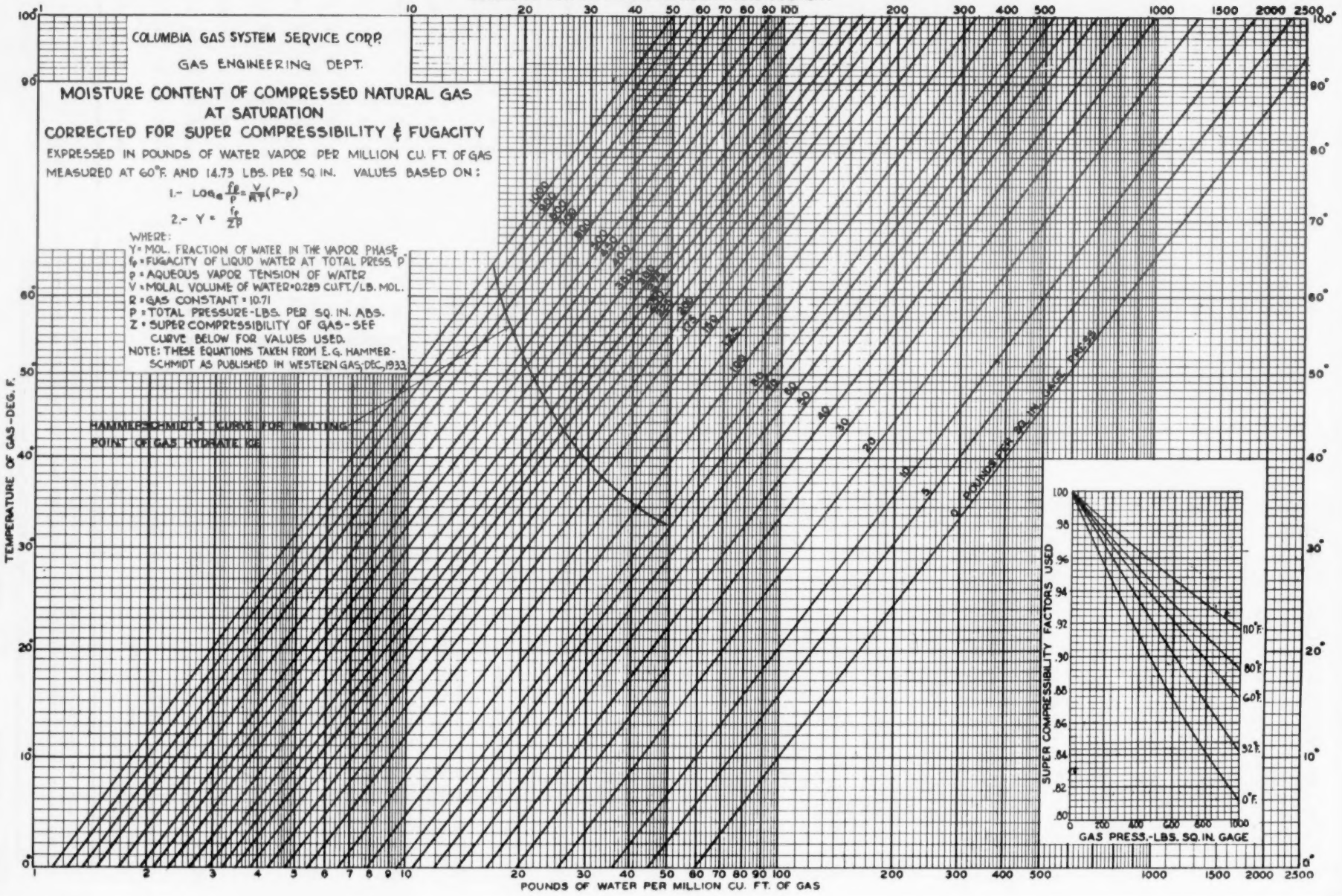
[a] A fluid is said to flow through the *run* of a tee when the flow is straight through the tee with no change of direction.

[b] A tee is said to be *reduced* ¼ if the internal area of the smaller connecting pipe is twenty-five per cent less than the internal area of the larger connecting pipe.

"North American Combustion Handbook." Copyright 1952, The North American Manufacturing Co.

MOISTURE CONTENT OF COMPRESSED NATURAL GAS

CORRECTED FOR SUPERCOMPRESSIBILITY AND FUGACITY


COLUMBIA GAS SYSTEM SERVICE CORP.
GAS ENGINEERING DEPT.
MOISTURE CONTENT OF COMPRESSED NATURAL GAS
AT SATURATION
CORRECTED FOR SUPER COMPRESSIBILITY & FUGACITY
EXPRESSED IN POUNDS OF WATER VAPOR PER MILLION CU. FT. OF GAS MEASURED AT 60°F. AND 14.73 LBS. PER SQ. IN. VALUES BASED ON:
1.- $\log_e \frac{f_e}{p} = \frac{V}{RT}(P-p)$
2.- $Y = \frac{f_e}{ZP}$
WHERE:
Y = MOL. FRACTION OF WATER IN THE VAPOR PHASE
f_e = FUGACITY OF LIQUID WATER AT TOTAL PRESS. P
p = AQUEOUS VAPOR TENSION OF WATER
V = MOLAL VOLUME OF WATER = 0.289 CU.FT./LB. MOL.
R = GAS CONSTANT = 10.71
P = TOTAL PRESSURE-LBS. PER SQ. IN. ABS.
Z = SUPER COMPRESSIBILITY OF GAS - SEE CURVE BELOW FOR VALUES USED.
NOTE: THESE EQUATIONS TAKEN FROM E.G. HAMMERSCHMIDT AS PUBLISHED IN WESTERN GAS, DEC., 1933
HAMMERSCHMIDT'S CURVE FOR MELTING POINT OF GAS HYDRATE ICE
TEMPERATURE OF GAS-DEG. F.
POUNDS OF WATER PER MILLION CU. FT. OF GAS
SUPER COMPRESSIBILITY FACTORS USED
GAS PRESS.-LBS. SQ. IN. GAGE
110°F.
80°F.
60°F.
32°F.
0°F.

COMPARISON OF DRYING AGENTS AND DEHYDRATION PROCESSES*

Type of dehydration	Advantages	Disadvantages	Remarks
Physical and physicochemical methods: Cooling	Inexpensive where cooling water is cheap or refrigeration is available as by-product of another process	Limited degree of dehydration. Possibility of plugging cooler tubes with ice or hydrates	
Compression		Possibility of hydrate formations in cooler. Not economical unless higher pressures are necessary for some other step in processing the gas	Dehydration plants follow compressors to take advantage of this effect
Absorption With liquids Brine (35–40% $CaCl_2$)	$CaCl_2$ very cheap. Small make-up required (0.1–0.2 lb $CaCl_2$/million cu ft, 0.393 lb/million cu ft)	Danger of electrolytic corrosion (not corrosive in natural gas unless pH is below 4.2). Tends to emulsify with accumulated absorption oil, entrained oil, etc., to decrease the efficiency of contacting equipment. Available dew-point depression limited by the solubility of $CaCl_2$. Hydrogen sulfide forms objectionable precipitates	Dew-point depression of 23–31° F
Diethylene glycol 96%	Relatively stable toward gases containing oxygen, sulfur, or carbon dioxide. Good dew-point depression. No danger of solidification of concentrated solutions	0.2–0.8 lb glycol lost/million cu ft through vaporization	Dew-point depression of 40–60° F
Lithium chloride	Highly hygroscopic. Nontoxic. Not hydrolyzed on boiling. Concentrated solutions not readily solidified. Less corrosive than $CaCl_2$.	Expensive. Commercial grades of lithium chloride reported to be corrosive because of impurities	Dew-point depression of 40–67° F
Glycerin 85%		Expensive. Tends to decompose on regeneration. At concentrations above 85%, it becomes too viscous for easy handling and foams easily	Dew-point depression of 30–33° F. Used in manufactured gas plants abroad
Zinc chloride	High dew-point depression	Possible acid corrosion	Dew-point depression of 40–55° F
Calcium chloride, 40%. Glycerin 20%	Inhibits crystallization of $CaCl_2$, allowing greater dew-point depression than straight $CaCl_2$	Hydrogen sulfide forms iron sulfide and causes foaming. Corrosive	Dew-point depression of 23–41° F. 0.02 to 0.06 gal of make-up/million cu ft on unit treating 110–130 million cu ft/day at 200 psi
Dow 8A ($CaBr_2$-$CaCl_2$ and/or $CaBr_2$)	High dew-point depression	Corrosive	Dew-point depression of 29–64° F
Amine, glycol, water, 7–8% monoethanolamine, 75–80% diethylene glycol, 12–16% water	Simultaneous removal of water, carbon dioxide, hydrogen sulfide, and other acid gases. Greater dew-point depression than glycol alone. Glycol reduces foaming tendencies of the amine	Amines volatilize and may be adsorbed on solid desiccants used in subsequent processing, necessitating occasional washing of the desiccant	Approximately 0.1 gal/million cu ft make-up required
With solids Lump $CaCl_2$. Molded from water, $CaCl_2$ and pulverized minerals or molten 72% $CaCl_2$ solution. Addition of pulverized carbon adds odor adsorption	Inexpensive. High capacity. Simple equipment required	Disintegrates in water, obstructing gas flow. Corrosive. Efficiency of dehydration varies with amount of water absorbed. Generally discarded when once exhausted	
Lump KOH, NaOH (same advantages and disadvantages as lump $CaCl_2$)			Used for liquefied petroleum gases
Adsorption. Granular adsorbents in general (silica gel, activated alumina, activated $CaSO_4$, activated bauxite, Florite Desiccant)	Good drying efficiency. Not corrosive. Easily regenerated. Easily handled.	Drying unit is cyclic rather than continuous. May be plugged or disintegrated by contaminants. Relatively high heat requirements for regeneration	Dew-point depression of 100° F or more
Chemical methods: Phosphorus pentoxide, P_2O_5	Highest drying efficiency. Good capacity	Difficult to handle. Corrosive. Becomes wet and sticky when saturated. Strongly acid.	Not used on large-scale gas drying
Barium oxide, BaO. Precipitated by heating $BaCO_3$	Will dehydrate at temp up to 1000° F. Cheap. Granular. Easily handled. Efficiency practically equal to P_2O_5. Large capacity.	Expands on hydration. Cannot be regenerated. Strong alkali	
Magnesium perchlorate (anhydrous; trihydrate)	Anhydrous form reported to have efficiency of P_2O_5. Large capacity. Contracts on adsorbing water. Chemically neutral	Not suitable for flammable or acid gases (reacts to form explosive perchloric acid	
Magnesium oxide, MgO	High activity	Low capacity	Not used on large-scale gas drying
Unslaked lime, CaO	High capacity	Corrosive. Hard to handle	
Combination methods: Single-stage Combined absorption-adsorption (Hi-Florite, alumina, $CaCl_2$, impregnated Drierite, etc.)	Relatively high capacity. Good efficiency	Loss of impregnated salt at high moisture saturation. Higher initial cost of desiccant. Corrosive (depending on nature of impregnated salt)	
Combined use of refrigeration and liquid absorbent	Higher dew-point depression than absorbent alone. Less danger of freeze-ups than refrigeration alone	Must be preceded by gasoline plant on natural-gas systems to prevent formation of condensate. Relatively complex plant operation	
Multiple-stage compression followed by solid adsorption	Compression followed by cooling reduces moisture load and size of equipment for solid absorbent	Economical only where higher pressures are necessary for some other purpose	

*Amero, Moore, and Cappell, *Chem. Eng. Progress*, April, 1947. Reproduced by permission of the authors, the Floridin Company, Warren, Pa., and the AIChE.

By permission, from "Natural Gas and Natural Gasoline," by R. L. Huntington. Copyright 1950. McGraw-Hill Book Company.

DIETHYLENE GLYCOL PROCESS

It has been established that solids resembling ice or snow form under certain conditions in natural gas transmission lines operating at elevated pressures. The solids, called hydrates, are a combination of water and hydrocarbon components of the gas and restrict flow in the line and clog pressure regulators and valves. Formation of hydrates can be eliminated by dehydrating the gas entering the lines or by the use of anti-freeze agents such as methanol. Dehydration is the method commonly used today to prevent hydrate formation in long distance lines, although anti-freeze agents are occasionally used. Most pipe line companies now specify a maximum permissible water content of gas entering their transmission systems.

The glycols are noted for their hygroscopicity which is one of the characteristics that has led to their widespread industrial use. Diethylene glycol has been successfully used to dehydrate natural gas for 15 years. Triethylene glycol has been used to dehumidify air since 1939, although it has been used for natural gas dehydration only recently. Both of these high boiling point glycols are thermally stable and do not oxidize or decompose in normal plant use. Make-up requirements are, therefore, small. The dew point depression obtainable in a glycol dehydration plant depends upon the temperature at which contact occurs, as well as the concentration of glycol in the circulated solution. More natural gas is dehydrated today by means of the glycols than by any other method.

A glycol type dehydration plant contains a minimum of equipment and inexpensive "package" units are available from several manufacturers. Many such plants do not require constant supervision and are, therefore, inexpensive to operate. The introduction of plants of this type makes possible dehydration of gas at the well head, thus eliminating the need for line heaters in field gathering systems. The glycol process consists of scrubbing the gas stream to be dehydrated with a glycol-water mixture in a plate or packed column. The dehydrated gas leaves the top of the contactor after passing through a mist extractor section. The dilute glycol solution which has removed the majority of the water from the gas stream leaves the bottom of the contactor and passes through a heat exchanger into a concentrator in which water is removed. In most plants the concentrator consists of a still provided with heat exchange surface for further heating the glycol solution and a fractionating column to reduce the loss of glycol vapor in the overhead. Heating may be accomplished by direct firing, steam or hot oil. Other methods of concentrating the solution, such as a vacuum distillation, are used in special cases. After leaving the concentrator, the glycol is heat exchanged with the incoming dilute solution, may be further cooled with water if necessary, and returned to the top of the contactor to repeat the dehydration cycle.

Carbide and Chemicals Company.

COMPRESSING AIR AND GAS

In compressing a gas, if the heat of compression is removed so as to keep its temperature constant, it is called Isothermal Compression.

If all the heat of compression is retained in the gas and used to increase its temperature, it is called Adiabatic Compression.

In present-day reciprocating compressors, the air or gas is compressed very nearly adiabatically. The water-jacketing brings the compression curve somewhat below the adiabatic, but the excess pressure required to force the air or gas through the valves makes the work done very close to that which would be calculated on the assumption of adiabatic compression for the entire cylinder of air or gas.

The following formulae apply to adiabatic compression:

$$\text{m. e. p.} = \frac{n}{n-1} P_1 \left\{ \left(\frac{P}{P_1} \right)^{\frac{n-1}{n}} - 1 \right\}$$

$$\text{i. h. p.} = \frac{\text{m. e. p.} \times L A N}{33{,}000}$$

Where

m. e. p. = mean effective pressure in compressor cylinder.
i. h. p. = indicated horse power.
n = ratio of the specific heat a constant pressure to the specific heat at constant volume for air or the gas being compressed (see the table opposite).
P_1 = inlet pressure—pounds per square inch absolute.
P_2 = discharge pressure—pounds per square inch absolute.
$r = \frac{P_2}{P_1}$
L = length of stroke of compressor in feet.
A = effective area of cylinder in square inches.
N = number of strokes per minute.

For adiabatic compression of air in a single stage:

$$\left.\begin{matrix}\text{i. h. p. per 100 cu. ft.} \\ \text{piston displacement} \\ \text{per min.}\end{matrix}\right\} = 1.51\, P_1 (r^{0.29} - 1)$$

Since the values of n for the principal constituents of manufactured gas do not differ substantially from that for air this formula may be applied to manufactured gas.

For natural gas (when n = 1.275) the corresponding formula would be:

$$\left.\begin{matrix}\text{i. h. p. per 100 cu. ft.} \\ \text{piston displacement} \\ \text{per min.}\end{matrix}\right\} 2.023\, P_1 (r^{0.216} - 1)$$

Indicated horse power must be divided by overall efficiency to obtain brake or delivered horse power.

Values of n for certain gases are as follows:

Acetylene (C_2H_2)	1.26
Air	1.403
Ammonia (NH_3)	1.310
Butane (C_4H_{10})	1.108
Carbon Dioxide (CO_2)	1.304
Carbon Monoxide (CO)	1.404
Ethane (C_2H_6)	1.22
Ethylene (C_2H_4)	1.255
Hydrogen (H_2)	1.410
Methane (CH_4)	1.31
Nitrogen (N_2)	1.404
Oxygen (O_2)	1.401
Propane (C_3H_8)	1.15
Water Vapor (H_2O)	1.324

Theoretical Horse Power Required to Compress 100 cu. ft. of Air from Atmospheric Pressure (14.7 lbs.) to Various Gauge Pressures:

Adiabatic Compression

Discharge Pressure	H. P.		Discharge Pressure	H. P.	
Lbs. Gauge	Single Stage	Two Stage	Lbs. Gauge	Single Stage	Two Stage
5	1.9	..	80	15.9	13.7
10	3.6	..	90	16.9	14.5
15	5.0	..	100	18.0	15.4
20	6.2	..	120	19.9	16.8
25	7.4	..	140	21.6	18.0
30	8.4	..	160	..	19.1
35	9.4	..	180	..	20.1
40	10.3	..	200	..	21.0
45	11.1	..	250	..	23.0
50	11.9	..	300	..	24.7
55	12.6	..	400	..	27.6
60	13.3	..	500	..	29.8
65	14.0	..	600	..	31.7
70	14.6	12.8	..	..	..
75	15.3	13.3	..	..	..

Approximate Brake Horse Power Required by Air Compressors per 100 cu. ft. of free air actually delivered.

Altitude Feet	Single Stage Lbs. per sq. in. gauge			Two Stage Lbs. per sq. in. gauge			
	60	80	100	60	80	100	125
0	16.3	19.5	22.1	14.7	17.1	19.1	21.3
1000	16.1	19.2	21.7	14.5	16.8	18.7	20.9
2000	15.9	18.9	21.3	14.3	16.5	18.4	20.5
3000	15.7	18.6	20.9	14.0	16.1	18.0	20.0
4000	15.4	18.2	20.6	13.8	15.8	17.7	19.6
5000	15.2	17.9	20.3	13.5	15.5	17.3	19.2

Actual Delivery

The actual delivery of a single-stage compressor pumping to 100 lbs. gauge from atmosphere will be from 65 per cent to 80 per cent of its piston displacement, depending upon its clearance space and valve gear. A compound machine compressing to 100 lbs. gauge with an inter-cooler pressure of about 27 lbs. gauge will deliver from 80 per cent to 90 per cent of its piston displacement.

Displacement

A convenient formula for calculating the displacement of a double-acting cylinder is — square of the Diameter (inches) × stroke (inches) × R.P.M. × .0009 = piston displacement (c.f.m.). This makes a reasonable allowance for the piston rod on all piston sizes from about 5" diam. to about 30" diam.

Data on Compression from "Compressed Air Data," Ingersoll-Rand Co.

Two Stage Compression

Two stage compression is generally used where the compression ratio r is in excess of 5 or 6. An intercooler is used between the two stages.

To secure the desired pressure with minimum work, equal work should be done in the two stages and the intermediate temperature of the gas should be reduced to that at the inlet.

Then $P_{Intermediate}$ should be $\sqrt{P_1 \times P_2}$

Also the compression ratio in each stage should equal the square root of the over-all compression ratio.

For manufactured gas (2 stage compression):

Total i.h.p. per 100 cu. ft. piston displacement per min. $\left.\right\} 3.02P_1 (r^{0.145} - 1)$

For natural gas (2 stage compression with n = 1.275):

Total i.h.p. per 100 cu. ft. piston displacement per min. $\left.\right\} 4.046 (r^{0.108} - 1)$

Compression Temperatures

For adiabatic compression

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = r^{\frac{n-1}{n}}$$

Where

T_1 = absolute inlet temperature.
T_2 = absolute discharge temperature.
P_1, P_2 and r as indicated above.

For manufactured gas $\frac{T_2}{T_1} = r^{0.29}$

For natural gas $\frac{T_2}{T_1} = r^{0.216}$

For two stage compression with intercooling to inlet temperature of the gas $\frac{T_2}{T_1} = r^{\frac{n-1}{2n}}$

Multi-Stage Compression

In general, multi-stage compression with intercooling between stages;

(1) Reduces final gas temperature.
(2) Reduces horsepower to compress.
(3) Partially removes entrained moisture.
(4) Increases volumetric efficiency by reducing clearance expansion loss.
(5) Generally reduces maximum piston loads below those which would be found in a single-stage compressor of equal displacement.

Ingersoll-Rand Co.

BRAKE HORSE POWER FORMULA

for compressing natural gas

$$BHP = \frac{R}{R \quad JP} \qquad \frac{5.16 \quad 124 \log. R}{0.97 - 0.03R}$$

where

BHP = brake horse power required to compress one million cubic feet of natural gas per day

R = ratio of compression = $\frac{P_1}{P_2}$

P_1 = compressor discharge, psia

P_2 = compressor suction, psia

J = factor for supercompressibility (assumed .022 per 100 psia

BHP PER MILLION CU. FT. OF GAS COMPRESSED

Ratio of Compression	BHP Per Million C.F. Per Day Natural Gas	Manufactured Gas	Ratio of Compression	BHP Per Million C.F. Per Day Natural Gas	Manufactured Gas	Ratio of Compression	BHP Per Million C.F. Per Day Natural Gas	Manufactured Gas
1.2	15.5	15.5	2.8	63.0	65.0	4.4	93.5	98.0
1.3	20.5	20.5	2.9	65.5	67.5	4.5	95.5	100.0
1.4	25.0	25.0	3.0	67.5	70.0	4.6	97.0	101.5
1.5	28.5	29.0	3.1	69.5	72.0	4.7	99.0	103.5
1.6	32.0	32.5	3.2	71.5	74.0	4.8	101.0	106.0
1.7	35.5	36.5	3.3	73.5	76.5	4.9	102.5	107.5
1.8	38.5	39.5	3.4	75.5	78.0	5.0	104.0	109.5
1.9	41.5	42.0	3.5	77.5	80.5	5.1	106.0	111.5
2.0	44.0	45.0	3.6	79.0	82.5	5.2	107.5	113.0
2.1	46.5	47.5	3.7	81.0	84.5	5.3	109.0	115.0
2.2	49.0	50.5	3.8	83.0	86.5	5.4	110.5	116.5
2.3	51.5	53.0	3.9	84.5	88.5	5.5	112.5	118.5
2.4	54.0	55.5	4.0	86.5	90.5	5.6	114.0	120.0
2.5	56.5	58.0	4.1	88.5	92.5	5.7	115.5	122.0
2.6	58.5	60.5	4.2	90.5	94.0	5.8	117.0	124.0
2.7	61.0	63.0	4.3	92.0	96.0	5.9	118.5	125.5
						6.0	120.0	127.0

Clark Bros. Company

Theoretical Temperatures Reached in Compressing Gas from Atmospheric Pressure (14.7 lbs.) and 60° F. to Various Gauge Pressures.

Discharge Pressure	Discharge Temperatures Single Stage Mf'd Gas	Natural Gas
5	106°	94°
10	144°	121°
15	177°	145°
20	207°	166°
25	234°	184°
30	258°	201°
35	280°	216°
40	301°	230°
45	320°	243°
50	339°	256°
55	356°	267°
60	373°	279°
65	389°	289°
70	404°	299°
75	419°	308°
80	432°	317°
90	459°	334°
100	484°	351°
120	533°	379°
140	569°	405°

Discharge Pressure	Discharge Temperatures Two Stage Mf'd Gas	Natural Gas
45	177°	145°
50	185°	150°
55	191°	155°
60	198°	160°
65	204°	164°
70	210°	168°
75	216°	172°
80	221°	176°
90	231°	183°
100	240°	189°
120	257°	200°
140	272°	211°
160	285°	219°
180	296°	227°
200	307°	235°
250	331°	250°
300	351°	264°

Figures for manufactured gas are also applicable to air.

Actual discharge temperatures will be somewhat less than the above figures because of radiation and of heat carried off by the cooling water from the cylinder jackets.

Example 1. One million cubic feet of gas per day, saturated with water vapor and at a temperature of 75° F., is delivered to the low pressure distribution system. There it is cooled to 60° F. What is the amount of condensation per day in the mains?

Moisture per M @ 75° F. ..... 1.35 lbs.
Moisture per M @ 70° F., 50 lbs. .26 lbs.

Condensation per M ..... .73 lbs.
1000 M × .73 = 730 lbs. condensation per day

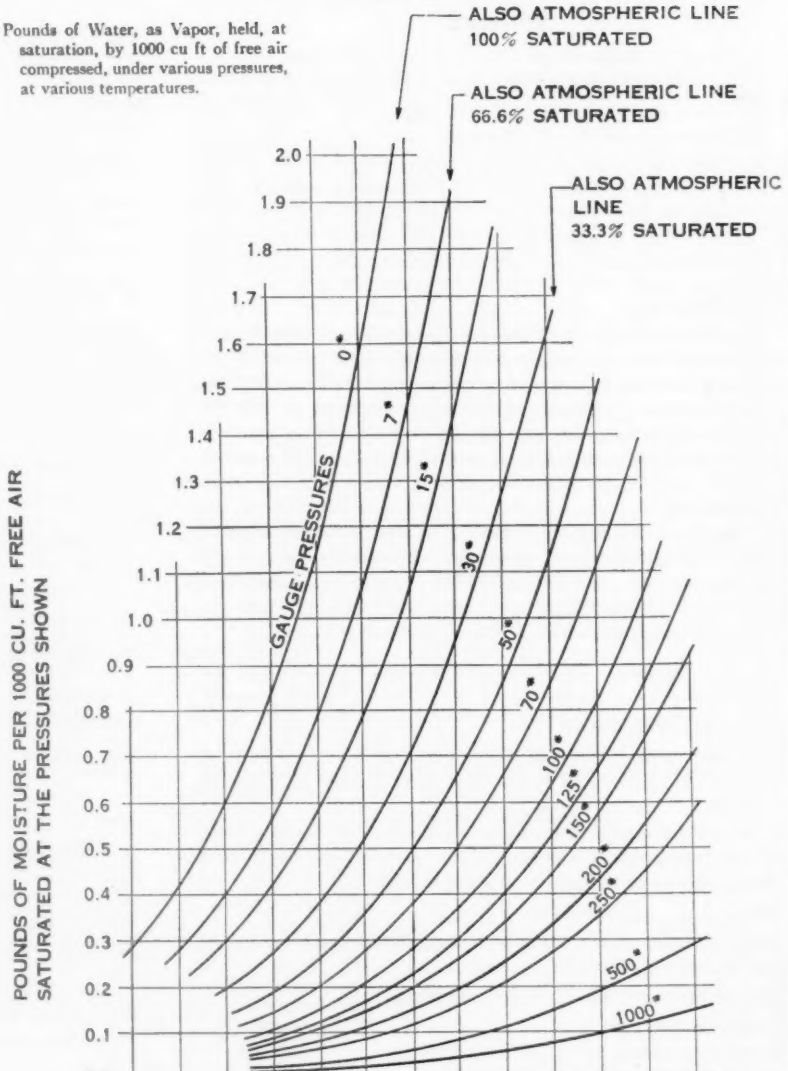
Example 2. Same conditions as Example 1, except that gas is sent out on medium pressure system at 7 lbs. per sq. in. pressure.

Moisture per M @ 75° F., 0 lbs. 1.35 lbs.
Moisture per M @ 60° F., 7 lbs. .56 lbs.

Condensation per M ..... .79 lbs.
1000 M × .79 = 790 lbs. condensation per day

GAS AND AIR SATURATION CHART

Pounds of Water, as Vapor, held, at saturation, by 1000 cu ft of free air compressed, under various pressures, at various temperatures.



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Example 3. One million cubic feet of gas per day, saturated with water vapor and at a temperature of 75° F., is compressed to 50 lbs. pressure, and then passes through an aftercooler where its temperature is reduced to 70° F. Thereafter it passes to the transmission system where its temperature is further reduced to 60° F. (a) How much moisture per day will be removed by a suitable separator at the outlet of the aftercooler? (b) How much moisture per day will be condensed in the transmission system at 50 lbs. and 60° F.? (c) To what pressure must the gas have fallen by the time its temperature dropped to 60° F. if there was no condensation in the transmission mains?

(a)

Moisture per M @ 75° F., 0 lbs. 1.35 lbs
Moisture per M @ 70° F., 50 lbs. .25 lbs

Condensation per M ..... 1.09 lbs
1000 M × 1.09 = 1090 lbs. condensation per day at aftercooler outlet.

(b)

Moisture per H @ 70° F., lbs. .. .26 lbs
Moisture per M @ 60° F., 50 lbs. .19 lbs
Condensation per M ..... .07 lbs

1000 M × .07 = 70 lbs. condensation per day in transmission mains.

(c)

Pressure at which .26 lbs. of moisture will saturate gas at a temperature of 60° F. 32 lbs. (Read from chart.)

INSTRUCTIONS FOR COMPUTING FLOW OF GAS THROUGH ORIFICE METERS

Table and figure numbers given here (pages 51 to 62) are the same as given in "Gas Measurement Committee Report, No. 2, American Gas Association, from which these data were taken. —Editor.

General Equation

In the measurement of most gases, and especially natural gas, it is almost the universal practice (in the United States) to express the flow in cubic feet per hour referred to some specified reference or base condition of pressure and temperature. For the calculation of the quantity of gas the committee* recommends the continued use of the formula:

$$Q_h = C' \sqrt{h_w p_f} \qquad (1)$$

in which

Q_h = Quantity rate of flow at base conditions, ft³/hr.
C' = Orifice flow constant.
h_w = Differential pressure in inches of water.
p_f = Absolute static pressure in Lbs./sq. in.

Orifice Flow Constant

The orifice flow constant, C', may be defined as the rate of flow, in cu. ft. per hour, at base conditions, when the extension, $\sqrt{h_w p_f}$ equals one. It was formerly known as the "flow coefficient." It is here called "orifice flow constant." It is to be calculated by the following equation:

$$C' = F_b \times F_r \times Y \times F_{pb} \times F_{tb} \times F_{tf} \times F_g \times F_{pv} \qquad (2)$$

in which

F_b = Basic orifice flow factor
F_r = Reynolds' number factor
Y = Expansion factor
F_{pb} = Pressure base factor
F_{tb} = Temperature base factor
F_{tf} = Flowing temperature factor
F_g = Specific gravity factor
F_{pv} = Supercompressibility factor

It will be noted that all of the factors used in calculating the orifice flow constants are familiar except F_r, F_b, Y and F_{pv}.

The values of all the factors F_b, F_r, etc., are obtained from the tables. The following method is for a meter with flange taps. The method for a meter with pipe taps will be exactly the same, except that the tables for pipe taps will be used.

Basic Orifice Flow Factor

The basic orifice flow factor, F_b, is taken directly from Table 4, for the correct orifice and pipe size. For sizes not listed in this table, the value of F_b may be found by calculation as explained in Appendix B of this report. (Interpolation should not be relied upon). The pipe diameter of the orifice sections, it is important to point out, should be within the limits specified in Table 2. If the value of D_i is outside of those limits the flow factors of Table 4 cannot be relied upon. Then the exact value of F_b should be calculated, for the particular value of "β" based on the actual value of D_i.

Reynolds' Number Factor

The Reynolds' number factor, F_r, is taken from Table 6. For its determination the average extension at which the meter operates must be known in addition to the orifice and pipe size.

The value of $\sqrt{h_w p_f}$ (extension) used in selecting the F_r factor from Table 6 may be based upon the meter record, or estimated from a knowledge of the average static pressure and the average differential at which the meter may operate. This extension, it should be noted, is an index with which a factor is selected, and does not enter directly into the computations. An extension value selected as suggested will probably be sufficiently close to the average operating conditions of the meter for selecting the proper value of F_r, especially since the variations in F_r corresponding to values of $\sqrt{h_w p_f}$ above or below the selected average will be compensating (plus or minus) over any appreciable length of time.

* From the Gas Measurement Committee Report, American Gas Association.

Orifice to Pipe Diameter	Recommended Maximum Allowable Tolerance between Measured inside Diameter of the upstream section of the meter run, and the Published "Approximate Internal Diameter", which was used in Computing Basic Orifice Constants of this Report.	
Ratio "β"	Flange Taps	Pipe Taps
.10 to .25	5.0%	3.5%
.25 to .35	3.0%	2.0%
.35 to .45	2.0%	1.0%
.45 to .55	1.5%	0.6%
.55 to .65	1.0%	0.3%
.65 to .75	0.5%	0.2%

TABLE 2

The tables, it should be noted, have been calculated by using average values of viscosity, 0.0000069 Lb./ft.-sec., of temperature, 520° F. absolute, and of gravity, 0.65, applying particularly to natural gas. If the gas being metered has a viscosity, temperature or gravity quite different from these, the value of F_r in Table 6 may not be applicable. However, for variations in viscosity from .0000059 to .0000079, in temperatures of from 490° to 550° F. absolute, or in specific gravity of from .55 to .75, the variations in the factor F_r would be well within the tolerances given for this report.

Expansion Factor

The expansion factor, Y, is to be taken from Tables 8, 9, or 10, depending upon the tap location from which the static pressure is taken. Here the ratio h_w/p_f is an index with which the value of Y is selected, and may be based upon the meter record, or estimated from the average static pressure and the average differential at which the meter may operate. The effects of operating variations from this "average" h_w/p_f will ordinarily be compensating.

For meters with flange connections, the variations to be expected in meter accuracy from the average will be greater or less depending on whether upstream, downstream or intermediate pressure connections are used. As the h/p ratio is increased, it will be observed, the use of the intermediate static pressure gives the minimum departure from the mean condition used in the selection of the expansion factor.

With orifice meters using "pipe taps" the variation from the mean estimated operating value of h/p used in the determination of the expansion factor (Y) result in the greatest variation in the value of Y when upstream static pressures are used. The use of intermediate static pressures in connection with pipe taps has little advantage, since it only slightly reduces the variations in Y resulting from departures from the mean. The use of downstream static pressures for this type of connection results in the least change in the values of Y due to changes in the values of the h/p ratio from the mean operating value.

Note—In use it may be found that a group of meters in the same locality, or operating under the same conditions, will have the same values for F_r, and Y. If this is true the flow constants in this group will be the same for all plates of the same size and ratio.

Pressure Base Factor

The pressure base factor, F_{pb}, is taken from Table 13.

Temperature Base Factor

The temperature base factor, F_{tb}, is taken from Table 14.

Flowing Temperature Factor

The flowing temperature factor, F_{tf}, is taken from Table 15, and should be based on the actual flowing temperature of the gas.

Specific Gravity Factor

The specific gravity factor, F_g, is taken from Table 16, and should be based on the actual specific gravity of the gas as determined by test, and the portion of table nearest to this used, with linear interpolation if necessary.

Supercompressibility Factor

The supercompressibility factor, F_{pv}, is taken from Table 17, and should be based on the actual supercompressibility ratio, N, as determined by test.

The development of the general hydraulic flow equation involves the actual density of the fluid at the point of measurement. In the measurement of gas this depends upon the flowing pressure and temperature. To translate the calculated volume at the flowing pressure and temperature to base pressure and temperature, it is necessary to apply the law for an ideal gas. All gases deviate from this ideal gas law to a greater or lesser extent. This deviation has been termed "Supercompressibility." A factor to take account of this supercompressibility is necessary in the measurement of some gases. This factor is particularly appreciable at high line pressures. However, before any supercompressibility factor can be applied to the measurement of a particular gas, an actual determination of the deviation from the ideal gas law, over the range of flowing pressures and temperatures involved, must have been made.

Application and Examples

In the application of these factors, it will be noted that F_r, Y, F_{pb}, F_{tf}, F_g and F_{pv} are multipliers, and may be applied either to the basic orifice flow factor, F_b, or to the calculated quantity rate of flow, as preferred.

Examples of the calculation of the quantity rate of flow for various conditions, using the tables in this report follows:

Example 1.

Given:

D_1 = Line size = 8" Nominal inside diameter = 8.071" actual inside diameter.

D_2 = Orifice size = 1.000".

Meter equipped with Flange Taps, with static pressure from downstream tap.

T_f = Flowing temperature = 65° F.

P_b = 4 oz. above 14.4 Lb/sq. in. = 14.65 Lb/sq. in. absolute = pressure base.

T_b = Temperature base = 50° F. = 510° absolute.

Specific gravity = .570.

Average differential head h_w = 50" Water.

Average downstream static pressure, p_f = 40 Lb/sq. in. absolute.

Supercompressibility ratio (by Test), N = 0.004.

Required:

The orifice flow constant and the quantity rate of flow for one hour at base conditions.

$$\beta = \frac{D_2}{D_1} = .1239$$

Published approximate inside diameter of pipe = 8.071

Ratio actual inside diameter to approximate inside diameter = 1.000

Per cent difference = 0.0 therefore Tables can be used.

Average $\sqrt{h_w p_f} = 44.72$

Average $\frac{h_w}{p_f} = 1.25$

From Table 4 for 1" plate in 8" line.

$F_b = 204.97$

From Table 6, 8" Line 1" Plate

for $\sqrt{h_w p_f} = 40$ $F_r = 1.0017$

$\sqrt{h_w p_f} = 50$ $F_r = 1.0014$

then at $\sqrt{h_w p_f} = 44.72$ $F_r = 1.0015$

From Table 9 (Y_2 for downstream static pressure)

at $\frac{h_w}{p_f} = 1.2$ and $\beta = .1$ and .2; $Y_2 = 1.0080$

at $\frac{h_w}{p_f} = 1.3$ and $\beta = .1$ and .2; $Y_2 = 1.0087$

Interpolating for

$\frac{h_w}{p_f} = 1.25$ and $\beta = .1239$; $Y_2 = 1.0084$

From Table 13

for 4 oz. above 14.4 Lb/sq. in.; $F_{pb} = .9829$

From Table 14

for $T_b = 50°$ F.; $F_{tb} = .9808$

From Table 15

for $T_f = 65°$ F.; $F_{tf} = .9952$

From Table 16

for Specific Gravity = .570; $F_g = 1.3245$

From Table 17

for N = .004 $F_{pv} = 1.002$

Then the orifice flow constant is:

$C' = 204.97 \times 1.0015 \times 1.0088 \times .9829 \times .9808 \times .9952 \times 1.3245 \times 1.0020 = 263.65 =$ Orifice Flow Constant

and the rate of flow for 1 hour at base conditions is:

$Q_h = 263.65 \sqrt{50 \times 40} = 11791$

The same value of Q_h is obtained if the computations are made in this order:

$Q_h = [204.97 \times \sqrt{50 \times 40}] \times (1.0015 \times 1.0088 \times 0.9829 \times 0.9808 \times 0.9952 \times 1.3245 \times 1.0020) = 9166.5 \times 1.286 = 11791$

ORIFICE METER TABLES FOR NATURAL GAS

The tolerances necessary in the use of any orifice meter do not warrant taking the values in these tables to be accurate beyond one in 500. Four figures are given in all cases solely to enable different computers to agree within 1 or 2 in the fourth significant figure regardless of whether it is on the right or left of the decimal.

In some of the tables values of the constants for a few of the smaller orifices are marked with an asterisk, these orifices have diameter ratios lower than the minimum value for which the formulas used were derived and this size of plate should not be used unless it is understood that the accuracy of measurement will be relatively low.

In preparing these tables the intermediate steps were usually carried out to 5 or 6 figures and the final value rounded off to the nearest fourth or fifth figure. When the fifth or sixth figure was a "5" the fourth or fifth figure was taken as the nearest *even* number.

TABLE 4 F_b BASIC ORIFICE FACTORS — FLANGE TAPS

Base Temperature = 60° F. Flowing Temperature = 60° F; $\sqrt{h_w p_f} = \infty$

Base Pressure = 14.4 Lb./Sq. in. abs; Specific Gravity = 1.0; $h_w/p_f = 0$

Pipe Sizes — Nominal and Actual Diameters

Orifice Diameter Inches	2" Std. 2.067	3" Std. 3.068	4" Std. 4.026	6" Std. 6.065	8" Std. 8.071	10" Std. 10.136	12" Std. 12.090	15¼" Std. 15.25
.250	13.002	12.996*	12.974*					
.375	29.079	29.026	28.989*					
.500	51.680	51.444	51.376	51.328*				
.625	81.129	80.426	80.218	80.080				
.750	117.77	116.16	115.67	115.30				
.875	162.11	158.70	157.81	157.08	156.82			
1.000	215.04	208.21	206.62	205.45	204.97			
1.125	277.93	264.97	262.21	260.39	259.69	259.27		
1.250	353.04	329.41	324.72	321.93	320.94	320.35	320.00	
1.375	443.44	402.10	394.35	390.11	388.73	387.95	387.47	
1.500	554.71	483.80	471.35	464.98	463.10	462.07	461.44	
1.625		575.47	556.06	546.62	544.07	542.73	541.93	541.06
1.750		678.61	648.93	635.11	631.64	629.94	628.93	627.85
1.875		794.99	750.50	730.55	725.90	723.73	722.48	721.15
2.000		926.76	861.42	833.06	826.86	824.11	822.56	820.95
2.125		1076.6	982.50	942.83	934.59	931.10	929.21	927.26
2.250		1251.2	1114.9	1060.0	1049.1	1044.7	1042.4	1040.1
2.375			1259.9	1184.9	1170.5	1165.1	1162.3	1159.5
2.500			1419.0	1317.7	1299.0	1292.1	1288.7	1285.4
2.625			1593.9	1458.7	1434.4	1425.8	1421.7	1417.9
2.750			1786.7	1608.3	1577.1	1566.4	1561.5	1557.0
2.875			2000.3	1767.0	1727.1	1713.8	1707.9	1702.6
3.000			2245.3	1935.2	1884.6	1868.2	1861.0	1854.9
3.125				2113.4	2049.7	2029.5	2020.9	2013.7
3.250				2302.4	2222.7	2197.8	2187.6	2179.2
3.375				2502.8	2403.7	2373.4	2361.1	2351.3
3.500				2715.7	2593.1	2556.1	2541.5	2530.1
3.625				2941.9	2791.1	2746.2	2728.9	2715.6
3.750				3182.5	2998.0	2943.8	2923.2	2907.9
3.875				3438.5	3214.2	3149.1	3124.6	3106.8
4.000				3711.4	3439.9	3362.1	3333.1	3312.5
4.250				4313.2	3922.0	3812.1	3772.0	3744.4
4.500				5013.1	4448.7	4295.5	4240.5	4203.8
4.750					5024.8	4812.8	4739.6	4691.2
5.000					5656.2	5369.9	5270.4	5206.7
5.250					6349.6	5965.5	5834.0	5751.2
5.500					7112.9	6604.3	6432.1	6324.8
5.750					7956.0	7289.8	7066.1	6928.6
6.000					8906.5	8026.3	7738.1	7563.0
6.250						8818.7	8450.0	8229.2
6.500						9672.0	9204.9	8927.9
6.750						10592	10006	9660.4
7.000						11587	10856	10428
7.250						12664	11759	11231
7.500						13851	12719	12073
7.750							13741	12954
8.000							14830	13877
8.250							15991	14843
8.500							17231	15856
8.750							18564	16918
9.000							20014	18031
9.250								19198
9.500								20426
9.750								21715
10.000								23070
10.250								24496
10.500								25997
10.750								27578
11.000								29253
11.250								31032

TABLE 6
F_r

REYNOLDS' NUMBER FACTORS — FLANGE TAPS

For 2" Line

Orifice Diam. Inches	$\sqrt{h_w p_f}$																		
	4.0	4.5	5.0	5.5	6.0	7.0	8.0	10	12	15	20	25	30	35	40	50	70	100	200
.250	1.0232	1.0206	1.0185	1.0168	1.0154	1.0132	1.0116	1.0093	1.0077	1.0062	1.0046	1.0037	1.0031	1.0026	1.0023	1.0019	1.0013	1.0009	1.0005
.375	1.0181	1.0161	1.0145	1.0132	1.0121	1.0104	1.0091	1.0073	1.0060	1.0048	1.0036	1.0029	1.0024	1.0021	1.0018	1.0015	1.0010	1.0007	1.0004
.500	1.0147	1.0131	1.0118	1.0107	1.0098	1.0084	1.0073	1.0059	1.0049	1.0039	1.0029	1.0024	1.0020	1.0017	1.0015	1.0012	1.0008	1.0006	1.0003
.625	1.0126	1.0112	1.0101	1.0092	1.0084	1.0072	1.0063	1.0051	1.0042	1.0034	1.0025	1.0020	1.0017	1.0014	1.0013	1.0010	1.0007	1.0005	1.0003
.750	1.0118	1.0105	1.0094	1.0086	1.0079	1.0067	1.0059	1.0047	1.0039	1.0031	1.0024	1.0019	1.0016	1.0013	1.0012	1.0009	1.0007	1.0005	1.0002
.875	1.0119	1.0106	1.0095	1.0087	1.0080	1.0068	1.0060	1.0048	1.0040	1.0032	1.0024	1.0019	1.0016	1.0014	1.0012	1.0010	1.0007	1.0005	1.0002
1.000	1.0129	1.0114	1.0103	1.0094	1.0086	1.0074	1.0064	1.0052	1.0043	1.0034	1.0026	1.0021	1.0017	1.0015	1.0013	1.0010	1.0007	1.0005	1.0003
1.125	1.0144	1.0128	1.0115	1.0104	1.0096	1.0082	1.0072	1.0057	1.0048	1.0038	1.0029	1.0023	1.0019	1.0016	1.0014	1.0011	1.0008	1.0006	1.0003
1.250	1.0161	1.0143	1.0129	1.0117	1.0108	1.0092	1.0081	1.0065	1.0054	1.0043	1.0032	1.0026	1.0022	1.0018	1.0016	1.0013	1.0009	1.0006	1.0003
1.375	1.0179	1.0159	1.0143	1.0130	1.0119	1.0102	1.0089	1.0072	1.0060	1.0048	1.0036	1.0029	1.0024	1.0020	1.0018	1.0014	1.0010	1.0007	1.0004
1.500	1.0193	1.0172	1.0155	1.0141	1.0129	1.0110	1.0097	1.0077	1.0064	1.0052	1.0039	1.0031	1.0026	1.0022	1.0019	1.0015	1.0011	1.0008	1.0004

For 4" Line

Orifice Diam. Inches	$\sqrt{h_w p_f}$																		
	4.0	4.5	5.0	5.5	6.0	7.0	8.0	10	12	15	20	25	30	35	40	50	70	100	200
.250	1.0264	1.0234	1.0211	1.0192	1.0176	1.0151	1.0132	1.0105	1.0088	1.0070	1.0053	1.0042	1.0035	1.0030	1.0026	1.0021	1.0015	1.0011	1.0005
.375	1.0227	1.0202	1.0181	1.0165	1.0151	1.0130	1.0113	1.0091	1.0076	1.0060	1.0045	1.0036	1.0030	1.0026	1.0023	1.0018	1.0013	1.0009	1.0005
.500	1.0195	1.0173	1.0156	1.0142	1.0130	1.0111	1.0097	1.0078	1.0065	1.0052	1.0039	1.0031	1.0026	1.0022	1.0019	1.0016	1.0011	1.0008	1.0004
.625	1.0167	1.0149	1.0134	1.0122	1.0112	1.0096	1.0084	1.0067	1.0056	1.0045	1.0033	1.0027	1.0022	1.0019	1.0017	1.0013	1.0010	1.0007	1.0003
.750	1.0144	1.0128	1.0116	1.0105	1.0096	1.0083	1.0072	1.0058	1.0048	1.0039	1.0029	1.0023	1.0019	1.0017	1.0014	1.0012	1.0008	1.0006	1.0003
.875	1.0126	1.0112	1.0100	1.0091	1.0084	1.0072	1.0063	1.0050	1.0042	1.0033	1.0025	1.0020	1.0017	1.0014	1.0013	1.0010	1.0007	1.0005	1.0003
1.000	1.0110	1.0098	1.0088	1.0080	1.0074	1.0063	1.0055	1.0044	1.0037	1.0029	1.0022	1.0018	1.0015	1.0013	1.0011	1.0009	1.0006	1.0004	1.0002
1.125	1.0099	1.0088	1.0079	1.0072	1.0066	1.0057	1.0050	1.0040	1.0033	1.0026	1.0020	1.0016	1.0013	1.0011	1.0010	1.0008	1.0006	1.0004	1.0002
1.250	1.0091	1.0081	1.0073	1.0066	1.0061	1.0052	1.0046	1.0036	1.0030	1.0024	1.0018	1.0015	1.0012	1.0010	1.0009	1.0007	1.0005	1.0004	1.0002
1.375	1.0086	1.0077	1.0069	1.0063	1.0057	1.0049	1.0043	1.0034	1.0029	1.0023	1.0017	1.0014	1.0011	1.0010	1.0009	1.0007	1.0005	1.0003	1.0002
1.500	1.0084	1.0075	1.0067	1.0061	1.0056	1.0048	1.0042	1.0034	1.0028	1.0022	1.0017	1.0013	1.0011	1.0010	1.0008	1.0007	1.0005	1.0003	1.0002
1.625	1.0085	1.0075	1.0068	1.0062	1.0056	1.0048	1.0042	1.0034	1.0028	1.0023	1.0017	1.0014	1.0011	1.0010	1.0008	1.0007	1.0005	1.0003	1.0002
1.750	1.0088	1.0078	1.0070	1.0064	1.0058	1.0050	1.0044	1.0035	1.0029	1.0023	1.0018	1.0014	1.0012	1.0010	1.0009	1.0007	1.0005	1.0004	1.0002
1.875	1.0092	1.0082	1.0074	1.0067	1.0062	1.0053	1.0046	1.0037	1.0031	1.0025	1.0018	1.0015	1.0012	1.0011	1.0009	1.0007	1.0005	1.0004	1.0002
2.000	1.0099	1.0088	1.0079	1.0072	1.0066	1.0057	1.0049	1.0040	1.0033	1.0026	1.0020	1.0016	1.0013	1.0011	1.0010	1.0008	1.0006	1.0004	1.0002
2.125	1.0107	1.0095	1.0085	1.0078	1.0071	1.0061	1.0053	1.0043	1.0036	1.0028	1.0021	1.0017	1.0014	1.0012	1.0011	1.0009	1.0006	1.0004	1.0002
2.250	1.0116	1.0103	1.0093	1.0084	1.0077	1.0066	1.0058	1.0046	1.0039	1.0031	1.0023	1.0019	1.0015	1.0013	1.0012	1.0009	1.0007	1.0005	1.0002
2.375	1.0125	1.0111	1.0100	1.0091	1.0084	1.0072	1.0063	1.0050	1.0042	1.0033	1.0025	1.0020	1.0017	1.0014	1.0013	1.0010	1.0007	1.0005	1.0003
2.500	1.0135	1.0120	1.0108	1.0098	1.0090	1.0077	1.0068	1.0054	1.0045	1.0036	1.0027	1.0022	1.0018	1.0015	1.0014	1.0011	1.0008	1.0005	1.0003
2.625	1.0145	1.0129	1.0116	1.0105	1.0096	1.0083	1.0072	1.0058	1.0048	1.0039	1.0029	1.0023	1.0019	1.0017	1.0014	1.0012	1.0008	1.0006	1.0003
2.750	1.0154	1.0137	1.0123	1.0112	1.0103	1.0088	1.0077	1.0062	1.0051	1.0041	1.0031	1.0025	1.0021	1.0018	1.0015	1.0012	1.0009	1.0006	1.0003
2.875	1.0162	1.0144	1.0130	1.0118	1.0108	1.0093	1.0081	1.0065	1.0054	1.0043	1.0032	1.0026	1.0022	1.0019	1.0016	1.0013	1.0009	1.0006	1.0003
3.000	1.0168	1.0150	1.0135	1.0123	1.0112	1.0096	1.0084	1.0067	1.0056	1.0045	1.0034	1.0027	1.0022	1.0019	1.0017	1.0013	1.0010	1.0007	1.0003

For 6" Line

Orifice Diam. Inches	$\sqrt{h_w p_f}$																		
	4.0	4.5	5.0	5.5	6.0	7.0	8.0	10	12	15	20	25	30	35	40	50	70	100	200
.500	1.0223	1.0198	1.0178	1.0162	1.0149	1.0127	1.0112	1.0089	1.0074	1.0059	1.0045	1.0036	1.0030	1.0025	1.0022	1.0018	1.0013	1.0009	1.0004
.625	1.0200	1.0178	1.0160	1.0146	1.0134	1.0114	1.0100	1.0080	1.0067	1.0053	1.0040	1.0032	1.0027	1.0023	1.0020	1.0016	1.0011	1.0008	1.0004
.750	1.0178	1.0158	1.0142	1.0129	1.0118	1.0101	1.0089	1.0071	1.0059	1.0047	1.0036	1.0028	1.0024	1.0020	1.0018	1.0014	1.0010	1.0007	1.0004
.875	1.0161	1.0143	1.0129	1.0117	1.0107	1.0092	1.0080	1.0064	1.0054	1.0043	1.0032	1.0026	1.0021	1.0018	1.0016	1.0013	1.0009	1.0006	1.0003
1.000	1.0144	1.0128	1.0115	1.0105	1.0096	1.0082	1.0072	1.0058	1.0048	1.0038	1.0029	1.0023	1.0019	1.0016	1.0014	1.0012	1.0008	1.0006	1.0003
1.125	1.0129	1.0115	1.0103	1.0094	1.0086	1.0074	1.0065	1.0052	1.0043	1.0034	1.0026	1.0021	1.0017	1.0015	1.0013	1.0010	1.0007	1.0005	1.0003
1.250	1.0116	1.0103	1.0093	1.0084	1.0077	1.0066	1.0058	1.0046	1.0039	1.0031	1.0023	1.0019	1.0015	1.0013	1.0012	1.0009	1.0007	1.0005	1.0002
1.375	1.0105	1.0093	1.0084	1.0076	1.0070	1.0060	1.0052	1.0042	1.0035	1.0028	1.0021	1.0017	1.0014	1.0012	1.0010	1.0008	1.0006	1.0004	1.0002
1.500	1.0095	1.0085	1.0076	1.0069	1.0063	1.0054	1.0048	1.0038	1.0032	1.0025	1.0019	1.0015	1.0013	1.0011	1.0010	1.0008	1.0005	1.0004	1.0002
1.625	1.0087	1.0077	1.0070	1.0063	1.0058	1.0050	1.0044	1.0035	1.0029	1.0023	1.0017	1.0014	1.0012	1.0010	1.0009	1.0007	1.0005	1.0003	1.0002
1.750	1.0081	1.0072	1.0065	1.0059	1.0054	1.0046	1.0040	1.0032	1.0027	1.0022	1.0016	1.0013	1.0011	1.0009	1.0008	1.0006	1.0005	1.0003	1.0002
1.875	1.0076	1.0067	1.0060	1.0055	1.0050	1.0043	1.0038	1.0030	1.0025	1.0020	1.0015	1.0012	1.0010	1.0009	1.0008	1.0006	1.0004	1.0003	1.0002
2.000	1.0072	1.0064	1.0058	1.0052	1.0048	1.0041	1.0036	1.0029	1.0024	1.0019	1.0014	1.0012	1.0010	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
2.125	1.0070	1.0062	1.0056	1.0051	1.0046	1.0040	1.0035	1.0028	1.0023	1.0019	1.0014	1.0011	1.0009	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
2.250	1.0068	1.0061	1.0055	1.0050	1.0046	1.0039	1.0034	1.0027	1.0023	1.0018	1.0014	1.0011	1.0009	1.0008	1.0007	1.0005	1.0004	1.0003	1.0001
2.375	1.0069	1.0061	1.0055	1.0050	1.0046	1.0039	1.0034	1.0027	1.0023	1.0018	1.0014	1.0011	1.0009	1.0008	1.0007	1.0005	1.0004	1.0003	1.0001
2.500	1.0070	1.0062	1.0056	1.0051	1.0046	1.0040	1.0035	1.0028	1.0023	1.0019	1.0014	1.0011	1.0009	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
2.625	1.0072	1.0064	1.0057	1.0052	1.0048	1.0041	1.0036	1.0029	1.0024	1.0019	1.0014	1.0011	1.0010	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
2.750	1.0075	1.0066	1.0060	1.0054	1.0050	1.0043	1.0037	1.0030	1.0025	1.0020	1.0015	1.0012	1.0010	1.0009	1.0007	1.0006	1.0004	1.0003	1.0001
2.875	1.0079	1.0070	1.0063	1.0057	1.0052	1.0045	1.0039	1.0031	1.0026	1.0021	1.0016	1.0013	1.0010	1.0009	1.0008	1.0006	1.0004	1.0003	1.0002
3.000	1.0083	1.0074	1.0066	1.0060	1.0055	1.0047	1.0042	1.0033	1.0028	1.0022	1.0017	1.0013	1.0011	1.0009	1.0008	1.0007	1.0005	1.0003	1.0002
3.125	1.0088	1.0078	1.0071	1.0064	1.0059	1.0050	1.0044	1.0035	1.0029	1.0024	1.0018	1.0014	1.0012	1.0010	1.0009	1.0007	1.0005	1.0004	1.0002
3.250	1.0094	1.0084	1.0075	1.0068	1.0063	1.0054	1.0047	1.0038	1.0031	1.0025	1.0019	1.0015	1.0013	1.0011	1.0009	1.0008	1.0005	1.0004	1.0002
3.375	1.0100	1.0089	1.0080	1.0073	1.0067	1.0057	1.0050	1.0040	1.0033	1.0027	1.0020	1.0016	1.0013	1.0011	1.0010	1.0008	1.0006	1.0004	1.0002
3.500	1.0106	1.0095	1.0085	1.0077	1.0071	1.0061	1.0053	1.0043	1.0035	1.0028	1.0021	1.0017	1.0014	1.0012	1.0011	1.0009	1.0006	1.0004	1.0002
3.625	1.0113	1.0100	1.0090	1.0082	1.0075	1.0065	1.0056	1.0045	1.0038	1.0030	1.0023	1.0018	1.0015	1.0013	1.0011	1.0009	1.0006	1.0005	1.0002
3.750	1.0120	1.0106	1.0096	1.0087	1.0080	1.0068	1.0060	1.0048	1.0040	1.0032	1.0024	1.0019	1.0016	1.0014	1.0012	1.0010	1.0007	1.0005	1.0002
3.875	1.0126	1.0112	1.0101	1.0092	1.0084	1.0072	1.0063	1.0050	1.0042	1.0034	1.0025	1.0020	1.0017	1.0014	1.0013	1.0010	1.0007	1.0005	1.0003
4.000	1.0133	1.0118	1.0106	1.0097	1.0089	1.0076	1.0066	1.0053	1.0044	1.0035	1.0027	1.0021	1.0018	1.0015	1.0013	1.0011	1.0008	1.0005	1.0003
4.250	1.0145	1.0129	1.0116	1.0105	1.0097	1.0083	1.0072	1.0058	1.0048	1.0039	1.0029	1.0023	1.0019	1.0017	1.0014	1.0012	1.0008	1.0006	1.0003
4.500	1.0155	1.0138	1.0124	1.0113	1.0103	1.0088	1.0077	1.0062	1.0052	1.0041	1.0031	1.0025	1.0021	1.0018	1.0015	1.0012	1.0009	1.0006	1.0003

TABLE 6 — Continued
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REYNOLDS' NUMBER FACTORS — FLANGE TAPS

For 8″ Line

Orifice Diam. Inches	$\sqrt{h_w p_f}$																		
	4.0	4.5	5.0	5.5	6.0	7.0	8.0	10	12	15	20	25	30	35	40	50	70	100	200
.875	1.0185	1.0165	1.0148	1.0135	1.0124	1.0106	1.0093	1.0074	1.0062	1.0049	1.0037	1.0030	1.0025	1.0021	1.0019	1.0015	1.0011	1.0007	1.0004
1.000	1.0170	1.0151	1.0136	1.0124	1.0113	1.0097	1.0085	1.0068	1.0057	1.0045	1.0034	1.0027	1.0023	1.0019	1.0017	1.0014	1.0010	1.0007	1.0003
1.125	1.0156	1.0138	1.0125	1.0113	1.0104	1.0089	1.0078	1.0062	1.0052	1.0042	1.0031	1.0025	1.0021	1.0018	1.0016	1.0012	1.0009	1.0006	1.0003
1.250	1.0143	1.0127	1.0114	1.0104	1.0095	1.0082	1.0071	1.0057	1.0048	1.0038	1.0029	1.0023	1.0019	1.0016	1.0014	1.0011	1.0008	1.0006	1.0003
1.375	1.0131	1.0116	1.0105	1.0095	1.0087	1.0075	1.0065	1.0052	1.0044	1.0035	1.0026	1.0021	1.0017	1.0015	1.0013	1.0010	1.0007	1.0005	1.0003
1.500	1.0120	1.0106	1.0096	1.0087	1.0080	1.0068	1.0060	1.0048	1.0040	1.0032	1.0024	1.0019	1.0016	1.0014	1.0012	1.0010	1.0007	1.0005	1.0002
1.625	1.0110	1.0098	1.0088	1.0080	1.0073	1.0063	1.0055	1.0044	1.0037	1.0029	1.0022	1.0018	1.0015	1.0013	1.0011	1.0009	1.0006	1.0004	1.0002
1.750	1.0101	1.0090	1.0081	1.0073	1.0067	1.0058	1.0050	1.0040	1.0034	1.0027	1.0020	1.0016	1.0013	1.0012	1.0010	1.0008	1.0006	1.0004	1.0002
1.875	1.0093	1.0082	1.0074	1.0067	1.0062	1.0053	1.0046	1.0037	1.0031	1.0025	1.0019	1.0015	1.0012	1.0011	1.0009	1.0007	1.0005	1.0004	1.0002
2.000	1.0086	1.0076	1.0069	1.0062	1.0057	1.0049	1.0043	1.0034	1.0029	1.0023	1.0017	1.0014	1.0011	1.0010	1.0009	1.0007	1.0005	1.0003	1.0002
2.125	1.0080	1.0071	1.0064	1.0058	1.0053	1.0045	1.0040	1.0032	1.0027	1.0021	1.0016	1.0013	1.0011	1.0009	1.0008	1.0006	1.0005	1.0003	1.0002
2.250	1.0074	1.0066	1.0059	1.0054	1.0050	1.0042	1.0037	1.0030	1.0025	1.0020	1.0015	1.0012	1.0010	1.0008	1.0007	1.0006	1.0004	1.0003	1.0002
2.375	1.0070	1.0062	1.0056	1.0051	1.0047	1.0040	1.0035	1.0028	1.0023	1.0019	1.0014	1.0011	1.0009	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
2.500	1.0066	1.0059	1.0053	1.0048	1.0044	1.0038	1.0033	1.0026	1.0022	1.0018	1.0013	1.0011	1.0009	1.0008	1.0007	1.0005	1.0004	1.0003	1.0001
2.625	1.0064	1.0056	1.0051	1.0046	1.0042	1.0036	1.0032	1.0025	1.0021	1.0017	1.0013	1.0010	1.0008	1.0007	1.0006	1.0005	1.0004	1.0003	1.0001
2.750	1.0061	1.0055	1.0049	1.0045	1.0041	1.0035	1.0031	1.0025	1.0020	1.0016	1.0012	1.0010	1.0008	1.0007	1.0006	1.0005	1.0004	1.0002	1.0001
2.875	1.0060	1.0053	1.0048	1.0044	1.0040	1.0034	1.0030	1.0024	1.0020	1.0016	1.0012	1.0010	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
3.000	1.0059	1.0053	1.0047	1.0043	1.0040	1.0034	1.0030	1.0024	1.0020	1.0016	1.0012	1.0009	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
3.125	1.0059	1.0053	1.0047	1.0043	1.0040	1.0034	1.0030	1.0024	1.0020	1.0016	1.0012	1.0009	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
3.250	1.0060	1.0053	1.0048	1.0044	1.0040	1.0034	1.0030	1.0024	1.0020	1.0016	1.0012	1.0010	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
3.375	1.0061	1.0054	1.0049	1.0044	1.0041	1.0035	1.0031	1.0024	1.0020	1.0016	1.0012	1.0010	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
3.500	1.0063	1.0056	1.0050	1.0046	1.0042	1.0036	1.0031	1.0025	1.0021	1.0017	1.0013	1.0010	1.0008	1.0007	1.0006	1.0005	1.0004	1.0003	1.0001
3.625	1.0065	1.0058	1.0052	1.0047	1.0043	1.0037	1.0033	1.0026	1.0022	1.0017	1.0013	1.0010	1.0009	1.0007	1.0007	1.0005	1.0004	1.0003	1.0001
3.750	1.0068	1.0060	1.0054	1.0049	1.0045	1.0039	1.0034	1.0027	1.0023	1.0018	1.0014	1.0011	1.0009	1.0008	1.0007	1.0005	1.0004	1.0003	1.0001
3.875	1.0071	1.0063	1.0057	1.0051	1.0047	1.0040	1.0035	1.0028	1.0024	1.0019	1.0014	1.0011	1.0009	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
4.000	1.0074	1.0066	1.0060	1.0054	1.0050	1.0042	1.0037	1.0030	1.0025	1.0020	1.0015	1.0012	1.0010	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
4.250	1.0082	1.0073	1.0066	1.0060	1.0055	1.0047	1.0041	1.0033	1.0028	1.0022	1.0016	1.0013	1.0011	1.0009	1.0008	1.0007	1.0005	1.0003	1.0002
4.500	1.0091	1.0081	1.0073	1.0067	1.0061	1.0052	1.0046	1.0037	1.0030	1.0024	1.0018	1.0015	1.0012	1.0010	1.0009	1.0007	1.0005	1.0004	1.0002
4.750	1.0101	1.0090	1.0081	1.0074	1.0068	1.0058	1.0051	1.0041	1.0034	1.0027	1.0020	1.0016	1.0014	1.0012	1.0010	1.0008	1.0006	1.0004	1.0002
5.000	1.0112	1.0099	1.0089	1.0081	1.0074	1.0064	1.0056	1.0045	1.0037	1.0030	1.0022	1.0018	1.0015	1.0013	1.0011	1.0009	1.0006	1.0004	1.0002
5.250	1.0122	1.0108	1.0097	1.0089	1.0081	1.0070	1.0061	1.0049	1.0041	1.0032	1.0024	1.0019	1.0016	1.0014	1.0012	1.0010	1.0007	1.0005	1.0002
5.500	1.0131	1.0117	1.0105	1.0095	1.0088	1.0075	1.0066	1.0053	1.0044	1.0035	1.0026	1.0021	1.0018	1.0015	1.0013	1.0011	1.0008	1.0005	1.0003
5.750	1.0140	1.0124	1.0112	1.0102	1.0093	1.0080	1.0070	1.0056	1.0047	1.0037	1.0028	1.0022	1.0019	1.0016	1.0014	1.0011	1.0008	1.0006	1.0003
6.000	1.0147	1.0131	1.0118	1.0107	1.0098	1.0084	1.0074	1.0059	1.0049	1.0039	1.0029	1.0024	1.0020	1.0017	1.0015	1.0012	1.0008	1.0006	1.0003

For 10″ Line

Orifice Diam. Inches	$\sqrt{h_w p_f}$																		
	4.0	4.5	5.0	5.5	6.0	7.0	8.0	10	12	15	20	25	30	35	40	50	70	100	200
1.125	1.0176	1.0157	1.0141	1.0128	1.0118	1.0101	1.0088	1.0071	1.0059	1.0047	1.0035	1.0028	1.0024	1.0020	1.0018	1.0014	1.0010	1.0007	1.0004
1.250	1.0164	1.0146	1.0131	1.0119	1.0109	1.0094	1.0082	1.0066	1.0055	1.0044	1.0033	1.0026	1.0022	1.0019	1.0016	1.0013	1.0009	1.0007	1.0003
1.375	1.0153	1.0136	1.0122	1.0111	1.0102	1.0087	1.0076	1.0061	1.0051	1.0041	1.0031	1.0024	1.0020	1.0017	1.0015	1.0012	1.0009	1.0006	1.0003
1.500	1.0142	1.0126	1.0114	1.0103	1.0095	1.0081	1.0071	1.0057	1.0047	1.0038	1.0028	1.0023	1.0019	1.0016	1.0014	1.0011	1.0008	1.0006	1.0003
1.625	1.0132	1.0117	1.0106	1.0096	1.0088	1.0075	1.0066	1.0053	1.0044	1.0035	1.0026	1.0021	1.0018	1.0015	1.0013	1.0011	1.0008	1.0005	1.0003
1.750	1.0122	1.0109	1.0098	1.0089	1.0082	1.0070	1.0061	1.0049	1.0041	1.0033	1.0024	1.0020	1.0016	1.0014	1.0012	1.0010	1.0007	1.0005	1.0002
1.875	1.0114	1.0101	1.0091	1.0083	1.0076	1.0065	1.0057	1.0046	1.0038	1.0030	1.0023	1.0018	1.0015	1.0013	1.0011	1.0009	1.0007	1.0005	1.0002
2.000	1.0106	1.0094	1.0085	1.0077	1.0071	1.0060	1.0053	1.0042	1.0035	1.0028	1.0021	1.0017	1.0014	1.0012	1.0011	1.0008	1.0006	1.0004	1.0002
2.125	1.0098	1.0087	1.0079	1.0072	1.0066	1.0056	1.0049	1.0039	1.0033	1.0026	1.0020	1.0016	1.0013	1.0011	1.0010	1.0008	1.0006	1.0004	1.0002
2.250	1.0091	1.0081	1.0073	1.0067	1.0061	1.0052	1.0046	1.0037	1.0030	1.0024	1.0018	1.0015	1.0012	1.0010	1.0009	1.0007	1.0005	1.0004	1.0002
2.375	1.0085	1.0076	1.0068	1.0062	1.0057	1.0049	1.0043	1.0034	1.0028	1.0023	1.0017	1.0014	1.0011	1.0010	1.0009	1.0007	1.0005	1.0003	1.0002
2.500	1.0080	1.0071	1.0064	1.0058	1.0053	1.0046	1.0040	1.0032	1.0027	1.0021	1.0016	1.0013	1.0011	1.0009	1.0008	1.0006	1.0005	1.0003	1.0002
2.625	1.0075	1.0066	1.0060	1.0054	1.0050	1.0043	1.0037	1.0030	1.0025	1.0020	1.0015	1.0012	1.0010	1.0009	1.0008	1.0006	1.0004	1.0003	1.0001
2.750	1.0070	1.0062	1.0056	1.0051	1.0047	1.0040	1.0035	1.0028	1.0023	1.0019	1.0014	1.0011	1.0009	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
2.875	1.0066	1.0059	1.0053	1.0048	1.0044	1.0038	1.0033	1.0027	1.0022	1.0018	1.0013	1.0011	1.0009	1.0008	1.0007	1.0005	1.0004	1.0003	1.0001
3.000	1.0063	1.0056	1.0050	1.0046	1.0042	1.0036	1.0032	1.0025	1.0021	1.0017	1.0013	1.0010	1.0008	1.0007	1.0006	1.0005	1.0004	1.0003	1.0001
3.125	1.0060	1.0053	1.0048	1.0044	1.0040	1.0034	1.0030	1.0024	1.0020	1.0016	1.0012	1.0010	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
3.250	1.0058	1.0051	1.0046	1.0042	1.0039	1.0033	1.0029	1.0023	1.0019	1.0015	1.0012	1.0009	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
3.375	1.0056	1.0050	1.0045	1.0041	1.0037	1.0032	1.0028	1.0022	1.0019	1.0015	1.0011	1.0009	1.0007	1.0006	1.0006	1.0004	1.0003	1.0002	1.0001
3.500	1.0054	1.0048	1.0044	1.0040	1.0036	1.0031	1.0027	1.0022	1.0018	1.0015	1.0011	1.0009	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
3.625	1.0054	1.0048	1.0043	1.0039	1.0036	1.0031	1.0027	1.0021	1.0018	1.0014	1.0011	1.0009	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
3.750	1.0053	1.0047	1.0042	1.0039	1.0035	1.0030	1.0026	1.0021	1.0018	1.0014	1.0011	1.0008	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
3.875	1.0053	1.0047	1.0042	1.0038	1.0035	1.0030	1.0026	1.0021	1.0018	1.0014	1.0011	1.0008	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
4.000	1.0053	1.0047	1.0043	1.0039	1.0035	1.0030	1.0027	1.0021	1.0018	1.0014	1.0011	1.0009	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
4.250	1.0055	1.0049	1.0044	1.0040	1.0037	1.0031	1.0027	1.0022	1.0018	1.0015	1.0011	1.0009	1.0007	1.0006	1.0006	1.0004	1.0003	1.0002	1.0001
4.500	1.0058	1.0051	1.0046	1.0042	1.0039	1.0033	1.0029	1.0023	1.0019	1.0015	1.0012	1.0009	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
4.750	1.0062	1.0055	1.0050	1.0045	1.0041	1.0035	1.0031	1.0025	1.0021	1.0017	1.0012	1.0010	1.0008	1.0007	1.0006	1.0005	1.0004	1.0002	1.0001
5.000	1.0068	1.0060	1.0054	1.0049	1.0045	1.0039	1.0034	1.0027	1.0022	1.0018	1.0014	1.0011	1.0009	1.0008	1.0007	1.0005	1.0004	1.0003	1.0001
5.250	1.0074	1.0066	1.0059	1.0054	1.0049	1.0042	1.0037	1.0030	1.0025	1.0020	1.0015	1.0012	1.0010	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
5.500	1.0081	1.0072	1.0065	1.0059	1.0054	1.0046	1.0040	1.0032	1.0027	1.0022	1.0016	1.0013	1.0011	1.0009	1.0008	1.0006	1.0005	1.0003	1.0002
5.750	1.0088	1.0079	1.0071	1.0064	1.0059	1.0051	1.0044	1.0035	1.0029	1.0024	1.0018	1.0014	1.0012	1.0010	1.0009	1.0007	1.0005	1.0004	1.0002
6.000	1.0096	1.0086	1.0077	1.0070	1.0064	1.0055	1.0048	1.0039	1.0032	1.0026	1.0019	1.0015	1.0013	1.0011	1.0010	1.0008	1.0006	1.0004	1.0002
6.250	1.0105	1.0093	1.0084	1.0076	1.0070	1.0060	1.0052	1.0042	1.0035	1.0028	1.0021	1.0017	1.0014	1.0012	1.0010	1.0008	1.0006	1.0004	1.0002
6.500	1.0113	1.0100	1.0090	1.0082	1.0075	1.0064	1.0056	1.0045	1.0038	1.0030	1.0023	1.0018	1.0015	1.0013	1.0011	1.0009	1.0006	1.0005	1.0002
6.750	1.0121	1.0107	1.0097	1.0088	1.0080	1.0069	1.0060	1.0048	1.0040	1.0032	1.0024	1.0019	1.0016	1.0014	1.0012	1.0010	1.0007	1.0005	1.0002
7.000	1.0128	1.0114	1.0103	1.0093	1.0086	1.0073	1.0064	1.0051	1.0043	1.0034	1.0026	1.0021	1.0017	1.0015	1.0013	1.0010	1.0007	1.0005	1.0003
7.250	1.0135	1.0120	1.0108	1.0098	1.0090	1.0077	1.0068	1.0054	1.0045	1.0036	1.0027	1.0022	1.0018	1.0015	1.0014	1.0011	1.0008	1.0005	1.0003
7.500	1.0141	1.0126	1.0113	1.0103	1.0094	1.0081	1.0071	1.0056	1.0047	1.0038	1.0028	1.0023	1.0019	1.0016	1.0014	1.0011	1.0008	1.0006	1.0003

TABLE 6 — Continued

F_r

REYNOLDS' NUMBER FACTORS — FLANGE TAPS

For 12" Line

Orifice Diam. Inches	$\sqrt{h_w p_f}$																		
	4.0	4.5	5.0	5.5	6.0	7.0	8.0	10	12	15	20	25	30	35	40	50	70	100	200
1.250	1.0180	1.0160	1.0144	1.0131	1.0120	1.0103	1.0090	1.0072	1.0060	1.0048	1.0036	1.0029	1.0024	1.0021	1.0018	1.0014	1.0010	1.0007	1.0004
1.375	1.0169	1.0150	1.0135	1.0123	1.0113	1.0097	1.0085	1.0068	1.0056	1.0045	1.0034	1.0027	1.0023	1.0019	1.0017	1.0014	1.0010	1.0007	1.0003
1.500	1.0159	1.0141	1.0127	1.0116	1.0106	1.0091	1.0079	1.0064	1.0053	1.0042	1.0032	1.0025	1.0021	1.0018	1.0016	1.0013	1.0009	1.0006	1.0003
1.625	1.0149	1.0133	1.0119	1.0109	1.0100	1.0085	1.0075	1.0060	1.0050	1.0040	1.0030	1.0024	1.0020	1.0017	1.0015	1.0012	1.0009	1.0006	1.0003
1.750	1.0140	1.0125	1.0112	1.0102	1.0093	1.0080	1.0070	1.0056	1.0047	1.0037	1.0028	1.0022	1.0019	1.0016	1.0014	1.0011	1.0008	1.0006	1.0003
1.875	1.0132	1.0117	1.0105	1.0096	1.0088	1.0075	1.0066	1.0053	1.0044	1.0035	1.0026	1.0021	1.0018	1.0015	1.0013	1.0011	1.0008	1.0005	1.0003
2.000	1.0123	1.0110	1.0099	1.0090	1.0082	1.0070	1.0062	1.0049	1.0041	1.0033	1.0025	1.0020	1.0016	1.0014	1.0012	1.0010	1.0007	1.0005	1.0002
2.125	1.0116	1.0103	1.0093	1.0084	1.0077	1.0066	1.0058	1.0046	1.0039	1.0031	1.0023	1.0019	1.0015	1.0013	1.0012	1.0009	1.0007	1.0005	1.0002
2.250	1.0109	1.0096	1.0087	1.0079	1.0072	1.0062	1.0054	1.0043	1.0036	1.0029	1.0022	1.0017	1.0014	1.0012	1.0011	1.0009	1.0006	1.0004	1.0002
2.375	1.0102	1.0090	1.0081	1.0074	1.0068	1.0058	1.0051	1.0041	1.0034	1.0027	1.0020	1.0016	1.0014	1.0012	1.0010	1.0008	1.0006	1.0004	1.0002
2.500	1.0096	1.0085	1.0076	1.0069	1.0064	1.0055	1.0048	1.0038	1.0032	1.0025	1.0019	1.0015	1.0013	1.0011	1.0010	1.0008	1.0005	1.0004	1.0002
2.625	1.0090	1.0080	1.0072	1.0065	1.0060	1.0051	1.0045	1.0036	1.0030	1.0024	1.0018	1.0014	1.0012	1.0010	1.0009	1.0007	1.0005	1.0004	1.0002
2.750	1.0084	1.0075	1.0067	1.0061	1.0056	1.0048	1.0042	1.0034	1.0028	1.0022	1.0017	1.0013	1.0011	1.0010	1.0008	1.0007	1.0005	1.0003	1.0002
2.875	1.0079	1.0070	1.0063	1.0058	1.0053	1.0045	1.0040	1.0032	1.0026	1.0021	1.0016	1.0013	1.0011	1.0009	1.0008	1.0006	1.0005	1.0003	1.0002
3.000	1.0075	1.0066	1.0060	1.0054	1.0050	1.0043	1.0037	1.0030	1.0025	1.0020	1.0015	1.0012	1.0010	1.0009	1.0007	1.0006	1.0004	1.0003	1.0001
3.125	1.0070	1.0063	1.0056	1.0051	1.0047	1.0040	1.0035	1.0028	1.0023	1.0019	1.0014	1.0011	1.0009	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
3.250	1.0067	1.0059	1.0053	1.0048	1.0044	1.0038	1.0033	1.0027	1.0022	1.0018	1.0013	1.0011	1.0009	1.0008	1.0007	1.0005	1.0004	1.0003	1.0001
3.375	1.0063	1.0056	1.0051	1.0046	1.0042	1.0036	1.0032	1.0025	1.0021	1.0017	1.0013	1.0010	1.0008	1.0007	1.0006	1.0005	1.0004	1.0003	1.0001
3.500	1.0060	1.0054	1.0048	1.0044	1.0040	1.0034	1.0030	1.0024	1.0020	1.0016	1.0012	1.0010	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
3.625	1.0058	1.0051	1.0046	1.0042	1.0038	1.0033	1.0029	1.0023	1.0019	1.0015	1.0012	1.0009	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
3.750	1.0055	1.0049	1.0044	1.0040	1.0037	1.0032	1.0028	1.0022	1.0018	1.0015	1.0011	1.0009	1.0007	1.0006	1.0006	1.0004	1.0003	1.0002	1.0001
3.875	1.0053	1.0047	1.0043	1.0039	1.0036	1.0030	1.0027	1.0021	1.0018	1.0014	1.0011	1.0009	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
4.000	1.0052	1.0046	1.0041	1.0038	1.0034	1.0030	1.0026	1.0021	1.0017	1.0014	1.0010	1.0008	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
4.250	1.0049	1.0044	1.0040	1.0036	1.0033	1.0028	1.0025	1.0020	1.0016	1.0013	1.0010	1.0008	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
4.500	1.0048	1.0043	1.0039	1.0035	1.0032	1.0028	1.0024	1.0019	1.0016	1.0013	1.0010	1.0008	1.0006	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
4.750	1.0049	1.0043	1.0039	1.0035	1.0032	1.0028	1.0024	1.0019	1.0016	1.0013	1.0010	1.0008	1.0006	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
5.000	1.0050	1.0044	1.0040	1.0036	1.0033	1.0028	1.0025	1.0020	1.0017	1.0013	1.0010	1.0008	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
5.250	1.0052	1.0046	1.0042	1.0038	1.0035	1.0030	1.0026	1.0021	1.0017	1.0014	1.0010	1.0008	1.0007	1.0006	1.0005	1.0004	1.0003	1.0002	1.0001
5.500	1.0055	1.0049	1.0044	1.0040	1.0037	1.0032	1.0028	1.0022	1.0018	1.0015	1.0011	1.0009	1.0007	1.0006	1.0006	1.0004	1.0003	1.0002	1.0001
5.750	1.0059	1.0053	1.0047	1.0043	1.0039	1.0034	1.0030	1.0024	1.0020	1.0016	1.0012	1.0009	1.0008	1.0007	1.0006	1.0005	1.0003	1.0002	1.0001
6.000	1.0064	1.0057	1.0051	1.0046	1.0043	1.0036	1.0032	1.0026	1.0021	1.0017	1.0013	1.0010	1.0009	1.0007	1.0006	1.0005	1.0004	1.0003	1.0001
6.250	1.0069	1.0061	1.0055	1.0050	1.0046	1.0040	1.0035	1.0028	1.0023	1.0018	1.0014	1.0011	1.0009	1.0008	1.0007	1.0006	1.0004	1.0003	1.0001
6.500	1.0075	1.0067	1.0060	1.0055	1.0050	1.0043	1.0038	1.0030	1.0025	1.0020	1.0015	1.0012	1.0010	1.0009	1.0008	1.0006	1.0004	1.0003	1.0002
6.750	1.0081	1.0072	1.0065	1.0059	1.0054	1.0046	1.0041	1.0033	1.0027	1.0022	1.0016	1.0013	1.0011	1.0009	1.0008	1.0007	1.0005	1.0003	1.0002
7.000	1.0088	1.0078	1.0070	1.0064	1.0059	1.0050	1.0044	1.0035	1.0029	1.0023	1.0018	1.0014	1.0012	1.0010	1.0009	1.0007	1.0005	1.0004	1.0002
7.250	1.0095	1.0084	1.0076	1.0069	1.0063	1.0054	1.0047	1.0038	1.0032	1.0025	1.0019	1.0015	1.0013	1.0011	1.0009	1.0008	1.0005	1.0004	1.0002
7.500	1.0102	1.0090	1.0081	1.0074	1.0068	1.0058	1.0051	1.0041	1.0034	1.0027	1.0020	1.0016	1.0014	1.0012	1.0010	1.0008	1.0006	1.0004	1.0002
7.750	1.0108	1.0096	1.0087	1.0079	1.0072	1.0062	1.0054	1.0043	1.0036	1.0029	1.0022	1.0017	1.0014	1.0012	1.0011	1.0009	1.0006	1.0004	1.0002
8.000	1.0115	1.0102	1.0092	1.0084	1.0077	1.0066	1.0058	1.0046	1.0038	1.0031	1.0023	1.0018	1.0015	1.0013	1.0012	1.0009	1.0007	1.0005	1.0002
8.250	1.0122	1.0108	1.0097	1.0089	1.0081	1.0070	1.0061	1.0049	1.0041	1.0032	1.0024	1.0019	1.0016	1.0014	1.0012	1.0010	1.0007	1.0005	1.0002
8.500	1.0128	1.0114	1.0102	1.0093	1.0085	1.0073	1.0064	1.0051	1.0043	1.0034	1.0026	1.0020	1.0017	1.0015	1.0013	1.0010	1.0007	1.0005	1.0003
8.750	1.0133	1.0119	1.0107	1.0097	1.0089	1.0076	1.0067	1.0053	1.0044	1.0036	1.0027	1.0021	1.0018	1.0015	1.0013	1.0011	1.0008	1.0005	1.0003
9.000	1.0138	1.0123	1.0111	1.0101	1.0092	1.0079	1.0069	1.0055	1.0046	1.0037	1.0028	1.0022	1.0018	1.0016	1.0014	1.0011	1.0008	1.0006	1.0003

TABLE 8-A Y_1 EXPANSION FACTORS — FLANGE TAPS

Static Pressure Taken from Upstream Taps

9.000	1.0138	1.0123	1.0111	1.0101	1.0092	1.0079	1.0069	1.0055	1.0046	1.0037	1.0028	1.0022	1.0018	1.0016	1.0014	1.0011	1.0008	1.0006	1.0003

TABLE 8-A Y_1 EXPANSION FACTORS — FLANGE TAPS

Static Pressure Taken from Upstream Taps

Line Size	ORIFICE SIZES																										
2"	1/8" 1/4"	3/8" 1/2"	5/8"	3/4"	7/8"	1"		1 1/8"				1 1/4"					1 3/8"							1 1/2"		
3"	1/8" 3/8"	1/2" 3/4"	5/8" 1"	1 1/8" 1 1/4"	1 3/8"	1 1/2"		1 5/8"		1 3/4"		1 7/8"				2"				2 1/8"				2 1/4"		
4"	1/8" 1/2"	5/8" 1"	1 1/8" 1 3/8"	1 1/2" 1 5/8"	1 3/4" 1 7/8"	2"	2 1/8"		2 1/4"	2 3/8"			2 1/2"			2 5/8"			2 3/4"			2 7/8"			3"	
6"	1/8" 7/8"	1" 1 1/2"	1 3/8" 2"	2 1/8" 2 1/2"	2 3/8" 2 7/8"	3"	3 1/8"	3 1/4"	3 3/8"	3 1/2"	3 5/8"		3 3/4"		3 7/8"		4"				4 1/4"				4 1/2"		
8"	1/8" 1 1/8"	1 1/4" 2"	2 1/8" 2 3/4"	2 7/8" 3 1/8"	3 1/2" 3 3/4"	3 7/8" 4"	4 1/4"		4 1/2"	4 3/4"			5"			5 1/4"			5 1/2"			5 3/4"			6"	
10"	1/8" 1 1/2"	1 5/8" 2 1/2"	2 5/8" 3 1/2"	3 3/8" 4 1/4"	4 1/2" 4 3/4"	5"	5 1/4"	5 1/2"	5 3/4"		6"		6 1/4"		6 1/2"			6 3/4"		7"		7 1/4"			7 1/2"		
12"	1/8" 1 3/4"	1 7/8" 3"	3 1/8" 4"	4 1/4" 5"	5 1/4" 5 1/2"	5 3/4" 6"	6 1/4"	6 1/2"	6 3/4"	7"	7 1/4"		7 1/2"		7 3/4"		8"		8 1/4"		8 1/2"		8 3/4"		9"		
15 1/4"	1/8" 2 1/4"	2 1/2" 3 3/4"	3 7/8" 5 1/4"	5 1/2" 6 1/4"	6 1/2" 7 1/4"	7 1/2" 7 3/4"	8"	8 1/4"	8 1/2"	8 3/4"	9"	9 1/4"	9 1/2"		9 3/4"		10"	10 1/4"		10 1/2"	10 3/4"		11"		11 1/4"		

$\frac{h_w}{P_1}$ Ratio	$\beta = \frac{D_2}{D_1}$ Ratio																										
	.1	.2	.3	.4	.45	.50	.52	.54	.56	.58	.60	.61	.62	.63	.64	.65	.66	.67	.68	.69	.70	.71	.72	.73	.74	.75
0.0	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	.9989	.9989	.9989	.9988	.9988	.9988	.9988	.9988	.9988	.9988	.9987	.9987	.9987	.9987	.9987	.9987	.9987	.9987	.9987	.9986	.9986	.9986	.9986	.9986	.9986	.9986
0.2	.9977	.9977	.9977	.9977	.9976	.9976	.9976	.9976	.9975	.9975	.9975	.9975	.9974	.9974	.9974	.9974	.9974	.9973	.9973	.9973	.9973	.9972	.9972	.9972	.9971	.9971
0.3	.9966	.9966	.9966	.9965	.9965	.9964	.9964	.9963	.9963	.9963	.9962	.9962	.9962	.9961	.9961	.9961	.9960	.9960	.9960	.9959	.9959	.9958	.9958	.9958	.9957	.9957
0.4	.9954	.9954	.9954	.9953	.9953	.9952	.9952	.9951	.9951	.9950	.9949	.9949	.9949	.9948	.9948	.9948	.9947	.9947	.9946	.9946	.9945	.9945	.9944	.9943	.9943	.9942
0.5	.9943	.9943	.9943	.9942	.9941	.9940	.9940	.9939	.9938	.9938	.9937	.9936	.9936	.9935	.9935	.9934	.9934	.9933	.9933	.9932	.9931	.9931	.9930	.9929	.9929	.9928
0.6	.9932	.9932	.9931	.9930	.9929	.9928	.9927	.9927	.9926	.9925	.9924	.9924	.9923	.9923	.9922	.9921	.9921	.9920	.9919	.9918	.9918	.9917	.9916	.9915	.9914	.9913
0.7	.9920	.9920	.9920	.9919	.9918	.9916	.9915	.9915	.9914	.9913	.9912	.9911	.9910	.9910	.9909	.9908	.9907	.9907	.9906	.9905	.9904	.9903	.9902	.9901	.9900	.9899
0.8	.9909	.9909	.9908	.9907	.9906	.9904	.9903	.9902	.9901	.9900	.9899	.9898	.9897	.9897	.9896	.9895	.9894	.9893	.9892	.9891	.9890	.9889	.9888	.9887	.9886	.9884
0.9	.9898	.9897	.9397	.9895	.9894	.9892	.9891	.9890	.9889	.9888	.9986	.9885	.9885	.9884	.9883	.9882	.9381	.9880	.9879	.9878	.9877	.9875	.9874	.9873	.9871	.9870
1.0	.9886	.9886	.9885	.9884	.9882	.9880	.9879	.9878	.9877	.9875	.9874	.9873	.9872	.9871	.9870	.9869	.9868	.9867	.9865	.9864	.9863	.9861	.9860	.9859	.9857	.9855
1.1	.9875	.9875	.9874	.9872	.9870	.9868	.9867	.9866	.9864	.9863	.9861	.9860	.9859	.9858	.9857	.9856	.9854	.9853	.9852	.9851	.9849	.9848	.9846	.9844	.9843	.9841
1.2	.9863	.9863	.9862	.9860	.9859	.9856	.9855	.9853	.9852	.9850	.9848	.9847	.9846	.9845	.9844	.9843	.9841	.9840	.9838	.9837	.9835	.9834	.9832	.9830	.9828	.9826
1.3	.9852	.9852	.9851	.9849	.9847	.9844	.9843	.9841	.9840	.9838	.9836	.9835	.9833	.9832	.9831	.9829	.9828	.9827	.9825	.9823	.9822	.9820	.9818	.9816	.9814	.9812
1.4	.9841	.9840	.9840	.9837	.9835	.9832	.9831	.9829	.9827	.9825	.9823	.9822	.9821	.9819	.9818	.9816	.9815	.9813	.9812	.9810	.9808	.9806	.9804	.9802	.9800	.9798
1.5	.9829	.9829	.9828	.9826	.9823	.9820	.9819	.9817	.9815	.9813	.9810	.9809	.9808	.9306	.9805	.9803	.9802	.9800	.9798	.9796	.9794	.9792	.9790	.9788	.9786	.9783
1.6	.9818	.9818	.9817	.9814	.9811	.9808	.9306	.9805	.9803	.9800	.9798	.9796	.9795	.9793	.9792	.9790	.9788	.9787	.9785	.9783	.9781	.9778	.9776	.9774	.9771	.9769
1.7	.9806	.9806	.9805	.9802	.9800	.9796	.9794	.9792	.9790	.9788	.9785	.9784	.9782	.9780	.9779	.9777	.9775	.9773	.9771	.9769	.9767	.9764	.9762	.9760	.9757	.9754
1.8	.9795	.9795	.9794	.9791	.9788	.9784	.9782	.9780	.9778	.9775	.9772	.9771	.9769	.9768	.9766	.9764	.9762	.9760	.9758	.9755	.9753	.9751	.9748	.9745	.9743	.9740
1.9	.9784	.9783	.9782	.9779	.9776	.9772	.9770	.9768	.9766	.9763	.9760	.9758	.9756	.9755	.9753	.9751	.9749	.9747	.9744	.9742	.9739	.9737	.9734	.9731	.9728	.9725
2.0	.9772	.9772	.9771	.9767	.9764	.9760	.9758	.9756	.9753	.9750	.9747	.9745	.9744	.9742	.9740	.9738	.9735	.9733	.9731	.9728	.9726	.9723	.9720	.9717	.9714	.9711
2.1	.9761	.9761	.9759	.9756	.9753	.9748	.9746	.9744	.9741	.9738	.9734	.9733	.9731	.9729	.9727	.9725	.9722	.9720	.9717	.9715	.9712	.9709	.9706	.9703	.9700	.9696
2.2	.9750	.9749	.9748	.9744	.9741	.9736	.9734	.9731	.9729	.9725	.9722	.9720	.9718	.9716	.9714	.9711	.9709	.9706	.9704	.9701	.9698	.9695	.9692	.9689	.9685	.9682
2.3	.9738	.9738	.9736	.9732	.9729	.9724	.9722	.9719	.9716	.9713	.9709	.9707	.9705	.9703	.9701	.9698	.9696	.9693	.9690	.9688	.9685	.9681	.9678	.9675	.9671	.9667
2.4	.9727	.9726	.9725	.9721	.9717	.9712	.9710	.9707	.9704	.9700	.9697	.9694	.9692	.9690	.9688	.9685	.9683	.9680	.9677	.9674	.9671	.9668	.9664	.9661	.9657	.9653
2.5	.9715	.9715	.9713	.9709	.9705	.9700	.9698	.9695	.9692	.9688	.9684	.9682	.9680	.9677	.9675	.9672	.9669	.9666	.9663	.9660	.9657	.9654	.9650	.9646	.9643	.9639
2.6	.9704	.9704	.9702	.9698	.9694	.9688	.9686	.9683	.9679	.9675	.9671	.9669	.9667	.9664	.9662	.9659	.9656	.9653	.9650	.9647	.9643	.9640	.9636	.9632	.9628	.9624
2.7	.9693	.9692	.9691	.9686	.9682	.9676	.9673	.9670	.9667	.9663	.9659	.9656	.9654	.9651	.9649	.9646	.9643	.9640	.9637	.9633	.9630	.9626	.9622	.9618	.9614	.9610
2.8	.9681	.9681	.9679	.9674	.9670	.9664	.9661	.9658	.9654	.9650	.9646	.9644	.9641	.9638	.9636	.9633	.9630	.9626	.9623	.9620	.9616	.9612	.9608	.9604	.9600	.9595
2.9	.9670	.9669	.9668	.9663	.9658	.9652	.9619	.9646	.9642	.9638	.9633	.9631	.9628	.9625	.9623	.9620	.9616	.9613	.9610	.9606	.9602	.9598	.9594	.9590	.9585	.9581
3.0	.9658	.9658	.9656	.9651	.9647	.9640	.9637	.9634	.9630	.9626	.9621	.9618	.9615	.9613	.9610	.9606	.9603	.9600	.9596	.9592	.9588	.9584	.9580	.9576	.9571	.9566
3.1	.9647	.9647	.9645	.9639	.9635	.9628	.9625	.9622	.9617	.9613	.9608	.9605	.9603	.9600	.9597	.9593	.9590	.9586	.9583	.9579	.9575	.9571	.9566	.9562	.9557	.9552
3.2	.9636	.9635	.9633	.9628	.9623	.9616	.9613	.9609	.9605	.9601	.9595	.9593	.9590	.9587	.9584	.9580	.9577	.9573	.9569	.9565	.9561	.9557	.9552	.9547	.9542	.9537
3.3	.9624	.9624	.9622	.9616	.9611	.9604	.9601	.9597	.9593	.9588	.9583	.9580	.9577	.9574	.9571	.9567	.9564	.9560	.9556	.9552	.9547	.9543	.9538	.9533	.9528	.9523
3.4	.9613	.9612	.9610	.9604	.9599	.9592	.9589	.9585	.9580	.9576	.9570	.9567	.9564	.9561	.9558	.9554	.9550	.9546	.9542	.9538	.9534	.9529	.9524	.9519	.9514	.9508
3.5	.9602	.9601	.9599	.9593	.9588	.9580	.9577	.9573	.9568	.9563	.9558	.9554	.9551	.9548	.9545	.9541	.9537	.9533	.9529	.9524	.9520	.9515	.9510	.9505	.9500	.9494
3.6	.9590	.9590	.9587	.9581	.9576	.9568	.9565	.9560	.9556	.9551	.9545	.9542	.9538	.9535	.9532	.9528	.9524	.9520	.9515	.9511	.9506	.9501	.9496	.9491	.9485	.9480
3.7	.9579	.9578	.9576	.9570	.9564	.9556	.9553	.9548	.9543	.9538	.9532	.9529	.9526	.9522	.9518	.9515	.9511	.9506	.9502	.9497	.9192	.9487	.9482	.9477	.9471	.9465
3.8	.9567	.9567	.9564	.9558	.9552	.9544	.9540	.9536	.9531	.9526	.9520	.9516	.9513	.9509	.9505	.9502	.9497	.9493	.9488	.9484	.9479	.9474	.9468	.9463	.9457	.9451
3.9	.9556	.9555	.9553	.9546	.9540	.9532	.9528	.9524	.9519	.9513	.9507	.9504	.9500	.9496	.9492	.9488	.9484	.9480	.9475	.9470	.9465	.9460	.9454	.9448	.9442	.9436
4.0	.9545	.9544	.9542	.9535	.9529	.9520	.9516	.9512	.9506	.9501	.9494	.9491	.9487	.9483	.9479	.9475	.9471	.9465	.9462	.9457	.9451	.9446	.9440	.9434	.9428	.9422

NOTE: Above tables are for use on natural gas and are based on ratio of specific heats equal to 1.30.

TABLE 9-A Y_2 EXPANSION FACTORS — FLANGE TAPS

Static Pressure Taken from Downstream Taps

Line Size	ORIFICE SIZES																										
2"	⅛" ¼"	⅜" ½"	⅝"	¾"	⅞"	1"		1⅛"				1¼"					1⅜"							1½"		
3"	⅛" ⅜"	½" ¾"	⅞" 1"	1⅛" 1¼"	1⅜"	1½"		1⅝"		1¾"		1⅞"				2"				2⅛"				2¼"		
4"	⅛" ½"	⅝" 1"	1⅛" 1⅜"	1½" 1⅝"	1¾" 1⅞"	2"	2⅛"		2¼"	2⅜"			2½"			2⅝"			2¾"			2⅞"			3"	
6"	⅛" ⅞"	1" 1½"	1⅝" 2"	2⅛" 2½"	2⅝" 2⅞"	3"	3⅛"	3¼"	3⅜"	3½"	3⅝"		3¾"		3⅞"		4"				4¼"				4½"	
8"	⅛" 1⅛"	1¼" 2"	2⅛" 2¾"	2⅞" 3⅜"	3½" 3¾"	3⅞" 4⅛"	4¼"		4½"	4¾"			5"			5¼"			5½"			5¾"			6"	
10"	⅛" 1½"	1⅝" 2½"	2⅝" 3½"	3⅝" 4¼"	4½" 4¾"	5"	5¼"	5½"	5¾"		6"		6¼"		6½"			6¾"		7"		7¼"			7½"	
12"	⅛" 1¾"	1⅞" 3"	3⅛" 4"	4¼" 5"	5¼" 5½"	5⅜" 6"	6¼"	6½"	6¾"	7"	7¼"		7½"		7¾"		8"		8¼"		8½"		8¾"		9"	
15¼"	⅛" 2¼"	2½" 3¾"	3⅞" 5¼"	5½" 6¼"	6½" 7¼"	7½" 7¾"	8"	8¼"	8½"	8¾"	9"	9¼"	9½"		9¾"		10"	10¼"		10½"	10¾"		11"		11¼"	
$\frac{h_w}{P_2}$	$\beta = \frac{D_2}{D_1}$, Ratio																										
Ratio	.1	.2	.3	.4	.45	.50	.52	.54	.56	.58	.60	.61	.62	.63	.64	.65	.66	.67	.68	.69	.70	.71	.72	.73	.74	.75	
0.1	1.0007	1.0007	1.0007	1.0006	1.0006	1.0006	1.0006	1.0006	1.0006	1.0006	1.0005	1.0005	1.0005	1.0005	1.0005	1.0005	1.0005	1.0005	1.0005	1.0004	1.0004	1.0004	1.0004	1.0004	1.0004	1.0004	
0.2	1.0013	1.0013	1.0013	1.0013	1.0013	1.0012	1.0012	1.0012	1.0012	1.0011	1.0011	1.0011	1.0011	1.0010	1.0010	1.0010	1.0010	1.0010	1.0009	1.0009	1.0009	1.0008	1.0008	1.0008	1.0008	1.0007	
0.3	1.0020	1.0020	1.0020	1.0020	1.0019	1.0018	1.0018	1.0018	1.0017	1.0017	1.0016	1.0016	1.0016	1.0016	1.0015	1.0015	1.0115	1.0014	1.0014	1.0014	1.0013	1.0013	1.0012	1.0012	1.0011	1.0011	
0.4	1.0027	1.0027	1.0027	1.0026	1.0026	1.0025	1.0024	1.0024	1.0023	1.0023	1.0022	1.0022	1.0021	1.0021	1.0021	1.0020	1.0020	1.0019	1.0019	1.0018	1.0018	1.0017	1.0017	1.0016	1.0015	1.0015	
0.5	1.0033	1.0033	1.0033	1.0032	1.0031	1.0030	1.0029	1.0029	1.0028	1.0028	1.0027	1.0027	1.0027	1.0026	1.0026	1.0025	1.0025	1.0024	1.0024	1.0023	1.0022	1.0022	1.0021	1.0020	1.0019	1.0019	
0.6	1.0040	1.0040	1.0040	1.0039	1.0038	1.0036	1.0036	1.0035	1.0034	1.0033	1.0032	1.0032	1.0031	1.0031	1.0030	1.0030	1.0029	1.0028	1.0027	1.0027	1.0026	1.0025	1.0024	1.0023	1.0022	1.0022	
0.7	1.0047	1.0047	1.0047	1.0045	1.0044	1.0043	1.0042	1.0041	1.0040	1.0039	1.0038	1.0033	1.0037	1.0036	1.0036	1.0035	1.0034	1.0033	1.0032	1.0031	1.0031	1.0030	1.0029	1.0028	1.0026	1.0025	
0.8	1.0053	1.0053	1.0053	1.0051	1.0050	1.0049	1.0048	1.0047	1.0046	1.0045	1.0044	1.0043	1.0043	1.0042	1.0041	1.0040	1.0039	1.0038	1.0037	1.0036	1.0035	1.0034	1.0033	1.0032	1.0031	1.0029	
0.9	1.0060	1.0060	1.0060	1.0058	1.0057	1.0055	1.0054	1.0053	1.0052	1.0050	1.0049	1.0048	1.0048	1.0047	1.0046	1.0045	1.0043	1.0042	1.0041	1.0040	1.0039	1.0039	1.0037	1.0036	1.0035	1.0033	
1.0	1.0067	1.0066	1.0066	1.0064	1.0063	1.0061	1.0060	1.0059	1.0058	1.0056	1.0055	1.0054	1.0053	1.0052	1.0051	1.0050	1.0049	1.0048	1.0046	1.0045	1.0044	1.0043	1.0041	1.0040	1.0039	1.0037	
1.1	1.0074	1.0073	1.0073	1.0071	1.0069	1.0067	1.0066	1.0065	1.0063	1.0061	1.0060	1.0059	1.0058	1.0057	1.0056	1.0055	1.0054	1.0053	1.0051	1.0050	1.0049	1.0047	1.0046	1.0044	1.0042	1.0040	
1.2	1.0080	1.0080	1.0079	1.0077	1.0075	1.0073	1.0072	1.0071	1.0069	1.0067	1.0066	1.0065	1.0064	1.0062	1.0061	1.0060	1.0059	1.0057	1.0056	1.0054	1.0053	1.0051	1.0050	1.0048	1.0046	1.0044	
1.3	1.0087	1.0087	1.0086	1.0084	1.0082	1.0080	1.0078	1.0077	1.0075	1.0073	1.0071	1.0070	1.0069	1.0067	1.0066	1.0065	1.0064	1.0062	1.0061	1.0059	1.0058	1.0056	1.0054	1.0052	1.0050	1.0048	
1.4	1.0094	1.0093	1.0093	1.0090	1.0088	1.0086	1.0084	1.0083	1.0081	1.0079	1.0077	1.0076	1.0074	1.0073	1.0072	1.0070	1.0069	1.0067	1.0065	1.0063	1.0062	1.0060	1.0058	1.0056	1.0054	1.0052	
1.5	1.0100	1.0100	1.0099	1.0097	1.0094	1.0091	1.0090	1.0088	1.0086	1.0084	1.0082	1.0081	1.0080	1.0078	1.0077	1.0075	1.0074	1.0072	1.0070	1.0068	1.0067	1.0065	1.0063	1.0060	1.0058	1.0056	
1.6	1.0108	1.0107	1.0106	1.0104	1.0101	1.0097	1.0097	1.0095	1.0093	1.0090	1.0088	1.0086	1.0085	1.0083	1.0081	1.0080	1.0078	1.0076	1.0075	1.0073	1.0071	1.0069	1.0066	1.0064	1.0062	1.0059	
1.7	1.0114	1.0114	1.0113	1.0110	1.0108	1.0104	1.0103	1.0101	1.0099	1.0096	1.0094	1.0092	1.0091	1.0089	1.0087	1.0086	1.0084	1.0082	1.0080	1.0078	1.0076	1.0074	1.0071	1.0069	1.0066	1.0064	
1.8	1.0121	1.0120	1.0120	1.0117	1.0114	1.0110	1.0108	1.0106	1.0104	1.0102	1.0100	1.0097	1.0096	1.0094	1.0092	1.0091	1.0089	1.0087	1.0084	1.0082	1.0080	1.0078	1.0075	1.0073	1.0070	1.0067	
1.9	1.0128	1.0127	1.0126	1.0123	1.0120	1.0116	1.0115	1.0112	1.0110	1.0107	1.0104	1.0103	1.0101	1.0099	1.0097	1.0095	1.0093	1.0091	1.0089	1.0087	1.0084	1.0082	1.0079	1.0077	1.0074	1.0071	
2.0	1.0134	1.0133	1.0132	1.0129	1.0126	1.0122	1.0121	1.0118	1.0116	1.0113	1.0110	1.0108	1.0106	1.0104	1.0102	1.0100	1.0098	1.0096	1.0094	1.0092	1.0089	1.0087	1.0084	1.0081	1.0078	1.0075	
2.1	1.0140	1.0140	1.0139	1.0136	1.0133	1.0129	1.0127	1.0124	1.0122	1.0119	1.0115	1.0114	1.0111	1.0110	1.0108	1.0105	1.0103	1.0101	1.0099	1.0096	1.0094	1.0091	1.0088	1.0085	1.0082	1.0079	
2.2	1.0147	1.0147	1.0146	1.0142	1.0139	1.0135	1.0133	1.0130	1.0128	1.0125	1.0121	1.0120	1.0118	1.0116	1.0114	1.0111	1.0109	1.0107	1.0104	1.0101	1.0098	1.0095	1.0094	1.0089	1.0086	1.0083	
2.3	1.0154	1.0154	1.0153	1.0149	1.0146	1.0141	1.0139	1.0136	1.0133	1.0130	1.0127	1.0125	1.0123	1.0121	1.0119	1.0116	1.0114	1.0111	1.0109	1.0106	1.0103	1.0100	1.0097	1.0093	1.0090	1.0086	
2.4	1.0160	1.0160	1.0159	1.0154	1.0151	1.0146	1.0144	1.0141	1.0138	1.0135	1.0133	1.0130	1.0128	1.0126	1.0124	1.0121	1.0119	1.0116	1.0114	1.0111	1.0108	1.0105	1.0102	1.0098	1.0095	1.0091	
2.5	1.0167	1.0167	1.0166	1.0162	1.0158	1.0153	1.0150	1.0148	1.0145	1.0141	1.0137	1.0135	1.0133	1.0131	1.0128	1.0126	1.0123	1.0120	1.0118	1.0115	1.0112	1.0109	1.0106	1.0102	1.0098	1.0094	
2.6	1.0174	1.0173	1.0172	1.0168	1.0164	1.0159	1.0156	1.0154	1.0151	1.0147	1.0143	1.0141	1.0139	1.0136	1.0134	1.0131	1.0128	1.0125	1.0123	1.0120	1.0116	1.0113	1.0110	1.0106	1.0102	1.0099	
2.7	1.0183	1.0182	1.0181	1.0176	1.0172	1.0167	1.0164	1.0161	1.0158	1.0154	1.0150	1.0148	1.0146	1.0143	1.0141	1.0138	1.0135	1.0132	1.0129	1.0126	1.0123	1.0119	1.0115	1.0111	1.0107	1.0103	
2.8	1.0187	1.0186	1.0185	1.0180	1.0176	1.0171	1.0168	1.0165	1.0162	1.0158	1.0154	1.0152	1.0149	1.0147	1.0144	1.0141	1.0139	1.0136	1.0132	1.0129	1.0126	1.0122	1.0118	1.0114	1.0110	1.0106	
2.9	1.0194	1.0194	1.0192	1.0187	1.0183	1.0177	1.0175	1.0172	1.0168	1.0164	1.0160	1.0157	1.0155	1.0152	1.0150	1.0147	1.0144	1.0141	1.0137	1.0134	1.0130	1.0127	1.0123	1.0119	1.0114	1.0110	
3.0	1.0200	1.0200	1.0198	1.0193	1.0189	1.0183	1.0180	1.0177	1.0173	1.0169	1.0165	1.0162	1.0160	1.0157	1.0155	1.0152	1.0149	1.0146	1.0142	1.0139	1.0135	1.0131	1.0127	1.0123	1.0119	1.0114	
3.1	1.0207	1.0206	1.0205	1.0200	1.0195	1.0189	1.0186	1.0183	1.0179	1.0175	1.0171	1.0168	1.0166	1.0163	1.0160	1.0157	1.0153	1.0150	1.0147	1.0143	1.0139	1.0135	1.0131	1.0127	1.0123	1.0118	
3.2	1.0213	1.0213	1.0211	1.0206	1.0201	1.0195	1.0192	1.0189	1.0185	1.0180	1.0176	1.0173	1.0171	1.0168	1.0165	1.0162	1.0158	1.0155	1.0152	1.0148	1.0144	1.0140	1.0136	1.0131	1.0127	1.0122	
3.3	1.0220	1.0220	1.0218	1.0213	1.0208	1.0202	1.0199	1.0195	1.0191	1.0186	1.0181	1.0178	1.0176	1.0173	1.0170	1.0166	1.0163	1.0159	1.0156	1.0152	1.0148	1.0144	1.0139	1.0135	1.0130	1.0125	
3.4	1.0227	1.0227	1.0225	1.0219	1.0214	1.0208	1.0205	1.0201	1.0197	1.0192	1.0187	1.0184	1.0182	1.0179	1.0175	1.0172	1.0169	1.0165	1.0161	1.0157	1.0153	1.0149	1.0144	1.0139	1.0135	1.0129	
3.5	1.0233	1.0233	1.0231	1.0225	1.0220	1.0214	1.0210	1.0207	1.0202	1.0198	1.0192	1.0190	1.0187	1.0183	1.0180	1.0177	1.0173	1.0169	1.0165	1.0161	1.0157	1.0153	1.0148	1.0143	1.0139	1.0133	
3.6	1.0240	1.0239	1.0237	1.0232	1.0227	1.0220	1.0216	1.0212	1.0208	1.0203	1.0198	1.0195	1.0192	1.0188	1.0185	1.0182	1.0178	1.0174	1.0170	1.0166	1.0162	1.0158	1.0153	1.0148	1.0143	1.0138	
3.7	1.0246	1.0246	1.0244	1.0238	1.0232	1.0225	1.0221	1.0217	1.0213	1.0208	1.0203	1.0200	1.0197	1.0193	1.0190	1.0187	1.0183	1.0179	1.0175	1.0171	1.0166	1.0162	1.0157	1.0152	1.0146	1.0141	
3.8	1.0252	1.0252	1.0250	1.0244	1.0238	1.0231	1.0227	1.0223	1.0219	1.0214	1.0209	1.0206	1.0203	1.0199	1.0196	1.0192	1.0189	1.0185	1.0180	1.0176	1.0171	1.0167	1.0162	1.0156	1.0151	1.0145	
3.9	1.0259	1.0259	1.0257	1.0250	1.0245	1.0237	1.0234	1.0229	1.0225	1.0220	1.0214	1.0211	1.0208	1.0205	1.0201	1.0197	1.0193	1.0189	1.0185	1.0180	1.0176	1.0171	1.0166	1.0160	1.0155	1.0149	
4.0	1.0265	1.0265	1.0263	1.0256	1.0251	1.0243	1.0240	1.0235	1.0231	1.0225	1.0220	1.0217	1.0213	1.0210	1.0206	1.0202	1.0198	1.0194	1.0190	1.0185	1.0180	1.0175	1.0170	1.0164	1.0159	1.0153	

NOTE: Above tables are for use on natural gas and are based on ratio of specific heats equal to 1.30.

TABLE 10-A Y_m EXPANSION FACTORS — FLANGE TAPS

Static Pressure, Mean of Upstream and Downstream

4.0	1.0265	1.0265	1.0263	1.0256	1.0251	1.0243	1.0240	1.0235	1.0231	1.0225	1.0220	1.0217	1.0213	1.0210	1.0206	1.0202	1.0198	1.0194	1.0190	1.0185	1.0180	1.0175	1.0170	1.0165	1.0160	1.0155	1.0150

NOTE: Above tables are for use on natural gas and are based on ratio of specific heats equal to 1.30.

TABLE 10-A Y_m EXPANSION FACTORS — FLANGE TAPS

Static Pressure, Mean of Upstream and Downstream

Line Size	ORIFICE SIZES																										
2"	1/8" 1/4"	3/8" 1/2"	5/8"	3/4"	7/8"	1"		1 1/8"				1 1/4"					1 3/8"							1 1/2"		
3"	1/8" 3/8"	1/2 3/4"	7/8" 1"	1 1/8" 1 1/4"	1 3/8"	1 1/2"		1 5/8"		1 3/4"		1 7/8"				2"				2 1/8"				2 1/4"		
4"	1/8" 1/2"	5/8" 1"	1 1/8" 1 3/8"	1 1/2" 1 5/8"	1 3/4" 1 7/8"	2"	2 1/8"		2 1/4"	2 3/8"			2 1/2"			2 5/8"			2 3/4"			2 7/8"			3"	
6"	1/8" 7/8"	1" 1 1/2"	1 5/8" 2"	2 1/8" 2 1/2"	2 5/8" 2 7/8"	3"	3 1/8"	3 1/4"	3 3/8"	3 1/2"	3 5/8"		3 3/4"		3 7/8"		4"				4 1/4"				4 1/2"		
8"	1/8" 1 1/8"	1 1/4 2"	2 1/8" 2 3/4"	2 7/8" 3 3/8"	3 1/2" 3 3/4"	3 7/8" 4"	4 1/4"		4 1/2"	4 3/4"			5"			5 1/4"			5 1/2"			5 3/4"			6"	
10"	1/8" 1 1/2"	1 5/8" 2 1/2"	2 3/8" 3 1/2"	3 5/8" 4 1/4"	4 1/2" 4 3/4"	5"	5 1/4"	5 1/2"	5 3/4"		6"		6 1/4"		6 1/2"			6 3/4"		7"		7 1/4"			7 1/2"	
12"	1/8" 1 3/4"	1 7/8 3"	3 1/8 4"	4 1/4" 5"	5 1/4" 5 1/2"	5 3/4" 6"	6 1/4"	6 1/2"	6 3/4"	7"	7 1/4"		7 1/2"		7 3/4"		8"		8 1/4"		8 1/2"		8 3/4"		9"		
15 1/4"	1/8" 2 1/4"	2 1/2" 3 3/4"	3 7/8" 5 1/4"	5 1/2" 6 1/4"	6 1/2" 7 1/4"	7 1/2" 7 3/4"	8"	8 1/4"	8 1/2"	8 3/4"	9"	9 1/4"	9 1/2"		9 3/4"		10"	10 1/4"		10 1/2"	10 3/4"		11"		11 1/4"		

h_w/P_m Ratio	$\beta = D_2/D_1$, Ratio																										
	.1	.2	.3	.4	.45	.50	.52	.54	.56	.58	.60	.61	.62	.63	.64	.65	.66	.67	.68	.69	.70	.71	.72	.73	.74	.75
0.1	.9998	.9998	.9998	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9996	.9996	.9996	.9996	.9996	.9996	.9996	.9996	.9996	.9995	.9995	.9995	.9995	.9995	.9995	.9995
0.2	.9995	.9995	.9995	.9995	.9994	.9994	.9994	.9994	.9993	.9993	.9993	.9993	.9992	.9992	.9992	.9992	.9992	.9991	.9991	.9991	.9991	.9990	.9990	.9990	.9989	.9989
0.3	.9993	.9993	.9993	.9992	.9992	.9991	.9991	.9990	.9990	.9990	.9989	.9989	.9989	.9988	.9988	.9988	.9987	.9987	.9987	.9986	.9986	.9986	.9985	.9985	.9984	.9984
0.4	.9991	.9991	.9990	.9990	.9989	.9988	.9988	.9987	.9987	.9986	.9986	.9985	.9985	.9984	.9984	.9984	.9983	.9983	.9982	.9982	.9981	.9981	.9980	.9980	.9979	.9978
0.5	.9988	.9988	.9988	.9987	.9986	.9985	.9985	.9984	.9983	.9983	.9982	.9981	.9981	.9981	.9980	.9980	.9979	.9978	.9978	.9977	.9977	.9976	.9975	.9974	.9974	.9973
0.6	.9986	.9986	.9985	.9984	.9984	.9982	.9982	.9981	.9980	.9979	.9978	.9978	.9977	.9977	.9976	.9975	.9975	.9974	.9973	.9973	.9972	.9971	.9970	.9969	.9968	.9967
0.7	.9984	.9984	.9983	.9982	.9981	.9979	.9979	.9978	.9977	.9976	.9975	.9974	.9973	.9973	.9972	.9971	.9971	.9970	.9969	.9968	.9967	.9966	.9965	.9964	.9963	.9962
0.8	.9981	.9981	.9981	.9979	.9978	.9976	.9976	.9975	.9974	.9972	.9971	.9970	.9970	.9969	.9968	.9967	.9967	.9965	.9965	.9964	.9963	.9962	.9961	.9960	.9959	.9957
0.9	.9979	.9979	.9978	.9977	.9975	.9973	.9973	.9972	.9971	.9969	.9968	.9967	.9967	.9966	.9965	.9964	.9963	.9962	.9961	.9960	.9959	.9957	.9956	.9955	.9953	.9952
1.0	.9977	.9977	.9976	.9975	.9973	.9971	.9970	.9969	.9968	.9967	.9965	.9964	.9963	.9962	.9961	.9960	.9959	.9958	.9957	.9955	.9954	.9953	.9951	.9950	.9948	.9947
1.1	.9975	.9974	.9974	.9972	.9971	.9968	.9967	.9966	.9965	.9963	.9961	.9960	.9959	.9958	.9957	.9956	.9955	.9953	.9952	.9951	.9949	.9948	.9946	.9945	.9943	.9941
1.2	.9973	.9973	.9972	.9970	.9968	.9966	.9964	.9963	.9961	.9960	.9958	.9957	.9955	.9954	.9953	.9952	.9951	.9949	.9948	.9946	.9945	.9943	.9941	.9940	.9938	.9936
1.3	.9971	.9970	.9970	.9967	.9965	.9963	.9961	.9960	.9958	.9956	.9954	.9953	.9952	.9951	.9949	.9948	.9946	.9945	.9943	.9942	.9940	.9938	.9936	.9934	.9933	.9931
1.4	.9968	.9968	.9967	.9965	.9963	.9960	.9958	.9957	.9955	.9953	.9951	.9949	.9948	.9947	.9945	.9944	.9942	.9941	.9939	.9938	.9936	.9934	.9932	.9930	.9928	.9926
1.5	.9966	.9966	.9965	.9962	.9960	.9957	.9955	.9954	.9952	.9950	.9948	.9946	.9945	.9944	.9942	.9941	.9939	.9937	.9935	.9933	.9932	.9929	.9927	.9925	.9923	.9920
1.6	.9964	.9964	.9962	.9960	.9957	.9954	.9952	.9950	.9948	.9946	.9944	.9943	.9941	.9940	.9938	.9937	.9935	.9933	.9931	.9929	.9927	.9925	.9922	.9920	.9918	.9915
1.7	.9962	.9962	.9960	.9958	.9955	.9952	.9950	.9948	.9946	.9943	.9941	.9939	.9938	.9936	.9934	.9933	.9931	.9929	.9927	.9925	.9923	.9921	.9918	.9916	.9913	.9910
1.8	.9959	.9959	.9958	.9955	.9953	.9949	.9947	.9945	.9943	.9940	.9937	.9936	.9934	.9932	.9930	.9928	.9927	.9925	.9923	.9920	.9918	.9916	.9913	.9911	.9908	.9905
1.9	.9957	.9957	.9956	.9953	.9950	.9948	.9944	.9942	.9940	.9937	.9934	.9933	.9931	.9929	.9927	.9925	.9923	.9921	.9919	.9916	.9914	.9911	.9908	.9906	.9903	.9900
2.0	.9955	.9954	.9953	.9950	.9946	.9942	.9940	.9938	.9935	.9932	.9929	.9927	.9925	.9923	.9921	.9919	.9917	.9915	.9913	.9910	.9908	.9905	.9902	.9899	.9896	.9892
2.1	.9953	.9953	.9952	.9948	.9945	.9940	.9938	.9936	.9933	.9930	.9927	.9925	.9923	.9921	.9919	.9917	.9915	.9913	.9910	.9908	.9905	.9902	.9899	.9896	.9893	.9890
2.2	.9951	.9951	.9950	.0047	.9943	.9938	.9936	.9934	.9931	.9927	.9924	.9922	.9920	.9918	.9916	.9913	.9911	.9908	.9906	.9903	.9900	.9897	.9894	.9892	.9888	.9884
2.3	.9949	.9949	.9947	.9944	.9940	.9936	.9933	.9931	.9928	.9924	.9921	.9919	.9917	.9915	.9913	.9910	.9908	.9905	.9902	.9900	.9897	.9894	.9891	.9887	.9884	.9980
2.4	.9947	.9947	.9945	.9941	.9938	.9933	.9930	.9927	.9924	.9921	.9917	.9915	.9913	.9911	.9909	.9906	.9904	.9901	.9898	.9895	.9892	.9889	.9886	.9882	.9878	.9875
2.5	.9945	.9944	.9943	.9938	.9935	.9930	.9927	.9924	.9921	.9918	.9914	.9912	.9909	.9907	.9905	.9902	.9900	.9897	.9894	.9891	.9888	.9885	.9881	.9878	.9874	.9870
2.6	.9943	.9942	.9941	.9936	.9933	.9928	.9925	.9922	.9919	.9915	.9911	.9909	.9907	.9904	.9902	.9899	.9896	.9893	.9890	.9887	.9884	.9880	.9876	.9873	.9869	.9865
2.7	.9941	.9941	.9939	.9934	.9930	.9925	.9922	.9919	.9916	.9912	.9907	.9905	.9903	.9900	.9898	.9895	.9892	.9889	.9886	.9883	.9880	.9876	.9872	.9869	.9864	.9860
2.8	.9939	.9938	.9937	.9932	.9928	.9922	.9919	.9916	.9913	.9909	.9904	.9902	.9900	.9897	.9895	.9892	.9889	.9886	.9882	.9879	.9875	.9871	.9867	.9864	.9859	.9855
2.9	.9937	.9936	.9934	.9929	.9925	.9919	.9916	.9913	.9909	.9905	.9901	.9899	.9896	.9893	.9891	.9888	.9885	.9882	.9878	.9874	.9871	.9867	.9863	.9859	.9855	.9850
3.0	.9935	.9934	.9932	.9927	.9923	.9917	.9914	.9911	.9907	.9903	.9898	.9895	.9892	.9890	.9887	.9884	.9881	.9877	.9874	.9870	.9867	.9863	.9859	.9854	.9850	.9845
3.1	.9932	.9932	.9930	.9925	.9920	.9914	.9911	.9908	.9904	.9900	.9895	.9892	.9890	.9887	.9884	.9881	.9877	.9874	.9870	.9867	.9863	.9859	.9854	.9850	.9845	.9840
3.2	.9931	.9931	.9929	.9923	.9919	.9912	.9909	.9905	.9901	.9897	.9892	.9889	.9886	.9883	.9880	.9877	.9873	.9870	.9866	.9862	.9858	.9854	.9850	.9845	.9840	.9835
3.3	.9929	.9928	.9926	.9921	.9916	.9909	.9906	.9902	.9898	.9894	.9889	.9886	.9883	.9880	.9877	.9873	.9870	.9866	.9863	.9859	.9854	.9850	.9845	.9841	.9836	.9831
3.4	.9927	.9926	.9924	.9918	.9913	.9907	.9903	.9899	.9895	.9890	.9885	.9882	.9789	.9876	.9873	.9859	.9866	.9862	.9858	.9854	.9850	.9845	.9841	.9836	.9831	.9825
3.5	.9925	.9924	.9922	.9916	.9911	.9905	.9901	.9897	.9893	.9888	.9883	.9880	.9877	.9873	.9870	.9866	.9863	.9859	.9855	.9850	.9846	.9841	.9837	.9832	.9826	.9821
3.6	.9923	.9923	.9920	.9914	.9909	.9902	.9898	.9894	.9890	.9885	.9878	.9876	.9873	.9869	.9866	.9862	.9859	.9855	.9851	.9846	.9842	.9837	.9833	.9827	.9822	.9816
3.7	.9921	.9920	.9918	.9912	.9907	.9899	.9895	.9891	.9887	.9882	.9876	.9873	.9870	.9866	.9863	.9859	.9855	.9851	.9847	.9842	.9838	.9833	.9828	.9822	.9817	.9811
3.8	.9919	.9918	.9916	.9910	.9905	.9897	.9893	.9889	.9884	.9879	.9873	.9870	.9866	.9863	.9859	.9855	.9851	.9847	.9843	.9838	.9834	.9829	.9824	.9818	.9813	.9807
3.9	.9918	.9917	.9915	.9908	.9902	.9894	.9890	.9886	.9881	.9876	.9870	.9867	.9863	.9860	.9856	.9852	.9848	.9844	.9839	.9835	.9830	.9825	.9820	.9814	.9808	.9802
4.0	.9916	.9915	.9913	.9906	.9900	.9892	.9888	.9884	.9879	.9873	.9.67	.9864	.9861	.9857	.9853	.9849	.9845	.9840	.9836	.9831	.9826	.9820	.9815	.9809	.9803	.9797

NOTE: Above tables are for use on natural gas and are based on ratio of specific heats equal to 1.30.

TABLE 13
F_{pb}

FACTORS TO CHANGE FROM A PRESSURE BASE OF 14.4 POUNDS PER SQUARE INCH ABSOLUTE TO SOME OTHER CONTRACT PRESSURE BASE

CONTRACT PRESSURE BASE			F_{pb}
Above 14.4		Absolute	Correction
Oz.	Lb.	Lb.	Factors
2	.125	14.525	.9914
4	.250	14.65	.9829
(30" Hg., Absolute)		14.73	.9776
6	.375	14.775	.9746
8	.500	14.90	.9664
10	.625	15.025	.9584
12	.750	15.15	.9505
14	.875	15.275	.9427
16	1.000	15.40	.9351
18	1.125	15.525	.9275
20	1.250	15.65	.9201
22	1.375	15.775	.9128
24	1.500	15.90	.9057
26	1.625	16.025	.8986
28	1.750	16.15	.8916
30	1.875	16.275	.8848
32	2.000	16.40	.8780
34	2.125	16.525	.8714
36	2.250	16.65	.8649
38	2.375	16.775	.8584
40	2.500	16.90	.8521
42	2.625	17.025	.8458
44	2.750	17.15	.8397
46	2.875	17.275	.8336
48	3.000	17.40	.8276

TABLE 14
F_{tb}

FACTORS TO CHANGE FROM A TEMPERATURE BASE OF 60° F. TO CONTRACT TEMPERATURE BASE

Temperature Degrees F.	F_{tb}	Temperature Degrees F.	F_{tb}
40	.9615	65	1.0096
41	.9635	66	1.0115
42	.9654	67	1.0135
43	.9673	68	1.0154
44	.9692	69	1.0173
45	.9712	70	1.0192
46	.9731	71	1.0212
47	.9750	72	1.0231
48	.9769	73	1.0250
49	.9788	74	1.0269
50	.9808	75	1.0288
51	.9827	76	1.0308
52	.9846	77	1.0327
53	.9865	78	1.0346
54	.9885	79	1.0365
55	.9904	80	1.0385
56	.9923	81	1.0404
57	.9942	82	1.0423
58	.9962	83	1.0442
59	.9981	84	1.0462
60	1.0000	85	1.0481
61	1.0019	86	1.0500
62	1.0038	87	1.0519
63	1.0058	88	1.0538
64	1.0077	89	1.0558
		90	1.0577

TABLE 15
F_{tf}

FACTOR TO CHANGE FROM FLOWING TEMPERATURE OF 60° FAHRENHEIT TO ACTUAL FLOWING TEMPERATURE

Temp. °F.	F_{tf}	Temp. °F.	F_{tf}	Temp. °F.	F_{tf}
1	1.0621	51	1.0088	101	.9628
2	1.0609	52	1.0078	102	.9619
3	1.0598	53	1.0068	103	.9610
4	1.0586	54	1.0058	104	.9602
5	1.0575	55	1.0048	105	.9594
6	1.0564	56	1.0039	106	.9585
7	1.0552	57	1.0029	107	.9577
8	1.0541	58	1.0019	108	.9568
9	1.0530	59	1.0010	109	.9560
10	1.0518	60	1.0000	110	.9551
11	1.0507	61	.9990	111	.9543
12	1.0496	62	.9981	112	.9535
13	1.0485	63	.9971	113	.9526
14	1.0474	64	.9962	114	.9518
15	1.0463	65	.9952	115	.9510
16	1.0452	66	.9943	116	.9501
17	1.0441	67	.9938	117	.9493
18	1.0430	68	.9924	118	.9485
19	1.0419	69	.9915	119	.9477
20	1.0408	70	.9905	120	.9469
21	1.0398	71	.9896	121	.9460
22	1.0387	72	.9887	122	.9452
23	1.0376	73	.9877	123	.9444
24	1.0365	74	.9868	124	.9436
25	1.0355	75	.9859	125	.9428
26	1.0344	76	.9850	126	.9420
27	1.0333	77	.9840	127	.9412
28	1.0323	78	.9831	128	.9404
29	1.0312	79	.9822	129	.9396
30	1.0302	80	.9813	130	.9388
31	1.0291	81	.9804	131	.9380
32	1.0281	82	.9795	132	.9372
33	1.0270	83	.9786	133	.9364
34	1.0260	84	.9777	134	.9356
35	1.0249	85	.9768	135	.9349
36	1.0239	86	.9759	136	.9341
37	1.0229	87	.9750	137	.9333
38	1.0218	88	.9741	138	.9325
39	1.0208	89	.9732	139	.9317
40	1.0198	90	.9723	140	.9309
41	1.0188	91	.9715	141	.9302
42	1.0178	92	.9706	142	.9294
43	1.0168	93	.9697	143	.9286
44	1.0158	94	.9688	144	.9279
45	1.0147	95	.9680	145	.9271
46	1.0137	96	.9671	146	.9263
47	1.0127	97	.9662	147	.9256
48	1.0117	98	.9653	148	.9248
49	1.0108	99	.9645	149	.9240
50	1.0098	100	.9636	150	.9233

TABLE 16
F_g

FACTORS TO ADJUST FOR SPECIFIC GRAVITY

Flowing Gravity G	F_g	Flowing Gravity G	F_g	Flowing Gravity G	F_g
.500	1.4142	.675	1.2172	.850	1.0847
.505	1.4072	.680	1.2127	.855	1.0815
.510	1.4003	.685	1.2082	.860	1.0783
.515	1.3935	.690	1.2039	.865	1.0752
.520	1.3868	.695	1.1995	.870	1.0721
.525	1.3801	.700	1.1952	.875	1.0690
.530	1.3736	.705	1.1910	.880	1.0660
.535	1.3672	.710	1.1868	.885	1.0630
.540	1.3608	.715	1.1826	.890	1.0600
.545	1.3546	.720	1.1785	.895	1.0570
.550	1.3484	.725	1.1744	.900	1.0541
.555	1.3423	.730	1.1704	.905	1.0512
.560	1.3363	.735	1.1664	.910	1.0483
.565	1.3304	.740	1.1625	.915	1.0454
.570	1.3245	.745	1.1586	.920	1.0426
.575	1.3188	.750	1.1547	.925	1.0398
.580	1.3131	.755	1.1509	.930	1.0370
.585	1.3074	.760	1.1471	.935	1.0342
.590	1.3019	.765	1.1433	.940	1.0314
.595	1.2964	.770	1.1396	.945	1.0287
.600	1.2910	.775	1.1359	.950	1.0260
.605	1.2856	.780	1.1323	.955	1.0233
.610	1.2804	.785	1.1287	.960	1.0206
.615	1.2752	.790	1.1251	.965	1.0180
.620	1.2700	.795	1.1215	.970	1.0153
.625	1.2649	.800	1.1180	.975	1.0127
.630	1.2599	.805	1.1146	.980	1.0102
.635	1.2549	.810	1.1111	.985	1.0076
.640	1.2500	.815	1.1077	.990	1.0050
.645	1.2451	.820	1.1043	.995	1.0025
.650	1.2403	.825	1.1010	1.000	1.0000
.655	1.2356	.830	1.0976		
.660	1.2309	.835	1.0944		
.665	1.2263	.840	1.0911		
.670	1.2217	.845	1.0879		

TABLE 17
F_{pv}

SUPERCOMPRESSIBILITY FACTORS

Supercompressibility Ratio N	Supercompressibility Factor F_{pv}	Supercompressibility Ratio N	Supercompressibility Factor F_{pv}
.000	1.0000	.070	1.0344
.002	1.0010	.072	1.0354
.004	1.0020	.074	1.0363
.006	1.0030	.076	1.0373
.008	1.0040	.078	1.0383
.010	1.0050	.080	1.0392
.012	1.0060	.082	1.0402
.014	1.0070	.084	1.0412
.016	1.0080	.086	1.0421
.018	1.0090	.088	1.0431
.020	1.0100	.090	1.0440
.022	1.0109	.092	1.0450
.024	1.0119	.094	1.0459
.026	1.0129	.096	1.0469
.028	1.0139	.098	1.0479
.030	1.0149	.100	1.0488
.032	1.0159	.102	1.0498
.034	1.0169	.104	1.0507
.036	1.0178	.106	1.0517
.038	1.0188	.108	1.0526
.040	1.0198	.110	1.0536
.042	1.0208	.112	1.0545
.044	1.0218	.114	1.0555
.046	1.0227	.116	1.0564
.048	1.0237	.118	1.0574
.050	1.0247	.120	1.0583
.052	1.0257	.122	1.0592
.054	1.0266	.124	1.0602
.056	1.0276	.126	1.0611
.058	1.0286	.128	1.0621
.060	1.0296	.130	1.0630
.062	1.0305	.132	1.0640
.064	1.0315	.134	1.0649
.066	1.0325	.136	1.0658
.068	1.0334	.138	1.0668
		.140	1.0677

FUEL CONSUMPTION OF GAS ENGINES

The amount of gas required per hp hour is dependent upon the efficiency of the engine and the percentage of full load at which it is operating. As the hp output of the engine decreases, the fuel consumption per hp hour increases. For estimating purposes, the following figures may safely be used.

Per Cent of Full Load	*Btu per HP Hr*
100	10,200
75	11,200
50	14,500
25	20,600

Inasmuch as most engines operate between 75 and 100 per cent of full load, the accepted practice is to figure 11,200 Btu per hp hour.

BTU PER BRAKE HORSEPOWER HOUR

Per Cent Load	*Small Bore below 7"*	*Large Bore above 7"*
100%	10,200	9,700
90%	10,300	9,900
80%	10,800	10,200
70%	11,300	10,900
60%	13,000	11,800
50%	14,500	13,000
40%	16,500	14,800
30%	19,000	17,000
20%	23,000	20,500

The above figures do not include the power required to operate the auxiliaries such as: cooling water pump, fan charging generator, etc.

The heat to be dissipated in a gas engine is approximately as follows:

Cooling water 3000 Btu per BHP hour or 50 Btu per minute per BHP.
Exhaust 3500 Btu per BHP hour or 59 Btu per minute per BHP.

The formula for figuring the quantity of cooling water required is as follows:

$$GPM = \frac{BHP \times Btu}{T \times 8.33}$$

where
GPM = Gallons per minute of cooling water
BHP = Brake horse power load on engine
Btu = Heat to be dissipated—Btu per minute
T = Difference in cooling water temperature in and out

The heat balance of a natural gas engine at full load is approximately as follows:

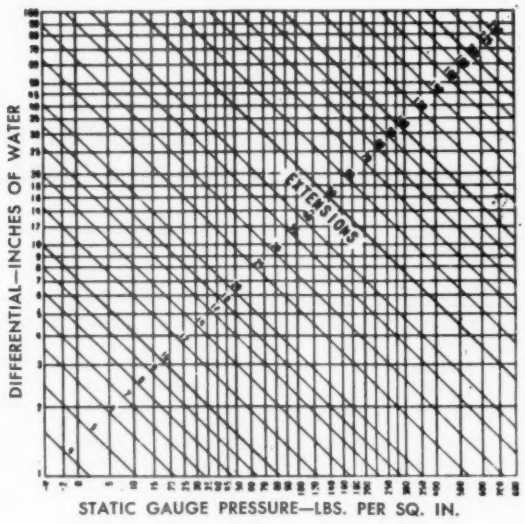
Brake horse power	25%
*Friction	7%
Cooling Water	30%
Exhaust	35%
Radiation	3%

* The heat generated in friction is dissipated in the cooling water and radiation.

AGA Gas Engine Handbook.

METHODS OF DETERMINING APPROXIMATE HOURLY FLOW THROUGH AN ORIFICE METER

(1) Locate differential on left margin.
(2) Trace to right to perpendicular line representing static gauge pressure on bottom scale.
(3) Read extension factor from diagonal lines.
(4) Hourly flow in cu. ft. = extension factor × orifice flow constants taken from tables No. XIV or XV.



Example: Assume an orifice meter with a 2″ orifice in a 4″ pipe run, having a differential of 40″ and a static pressure of 200 lbs., flange taps being used.
Then: Extension = 95
Orifice flow constant = 1070
Hourly flow = 95 × 1070 = 102,000 Cu. Ft.

APPROXIMATE HOURLY ORIFICE FLOW CONSTANTS—FLANGE TAPS

Based on .65 specific gravity gas at average atmospheric pressure and temperature. TABLE XIV

Orifice Diameter Inches	Pipe Sizes 2″ Std. (2.067)	3″ Std. (3.068)	4″ Std. (4.026)	6″ Std. (6.065)	8″ Std. (8.071)	10″ Std. (10.136)	12″ Std. (12.090)
.25	16	16	16				
.375	36	36	36				
.50	64	64	64	64			
.625	101	100	99	99			
.75	146	144	143	143			
.875	201	197	196	195	195		
1.00	267	258	256	255	254		
1.125	345	329	325	323	322	322	
1.25	438	409	403	399	398	397	397
1.375	550	499	489	484	482	481	481
1.50	688	600	585	577	574	573	572
1.625		714	690	678	675	673	672
1.75		842	805	788	783	781	780
1.875		986	931	906	900	898	896
2.00		1150	1070	1030	1030	1020	1020
2.125		1340	1220	1170	1160	1160	1150
2.25		1550	1380	1320	1300	1300	1290
2.375			1560	1470	1450	1450	1440
2.50			1760	1630	1610	1600	1600
2.625			1980	1810	1780	1770	1760
2.75			2220	2000	1960	1940	1940
2.875			2480	2190	2140	2130	2120
3.00			2790	2400	2340	2320	2310
3.125				2620	2540	2520	2510
3.25				2860	2760	2730	2710
3.375				3100	2980	2940	2930
3.50				3370	3220	3170	3150
3.625				3650	3460	3410	3390
3.75				3950	3720	3650	3630
3.875				4270	3990	3910	3880
4.00				4600	4270	4170	4130
4.25				5350	4860	4730	4680
4.50				6220	5520	5330	5260
4.75					6230	5970	5880
5.00					7020	6660	6540
5.25					7880	7400	7240
5.50					8820	8190	7980
5.75					9870	9040	8760
6.00					11000	9960	9600
6.25						10900	10500
6.50						12000	11400
6.75						13100	12400
7.00						14400	13500
7.25						15700	14600
7.50						17200	15800
7.75							17000
8.00							18400
8.25							19800
8.50							21400
8.75							23000
9.00							24800

Note: The above Flow Constants are only approximate values and should not be used in Commercial Gas Measurement Computations.

APPROXIMATE HOURLY ORIFICE FLOW CONSTANTS—PIPE TAPS

Based on .65 specific gravity gas at average atmospheric pressure and temperature. TABLE XV

Orifice Diameter Inches	Pipe Sizes 2″ Std. (2.067)	3″ Std. (3.068)	4″ Std. (4.026)	6″ Std. (6.065)	8″ Std. (8.071)	10″ Std. (10.136)	12″ Std. (12.090)
.25	16	16	16				
.375	37	36	36				
.50	67	65	65	64			
.625	107	103	101	100			
.75	159	150	147	145			
.875	225	207	202	198	197		
1.00	309	276	266	259	257		
1.125	416	357	341	330	326	325	
1.25	556	453	428	410	404	402	400
1.375	741	566	526	499	491	487	485
1.50		698	637	598	586	581	578
1.625		854	764	708	691	683	679
1.75		1040	906	829	805	795	789
1.875		1260	1070	961	929	915	908
2.00		1530	1250	1110	1060	1050	1040
2.125		1860	1460	1260	1210	1180	1170
2.25			1690	1430	1360	1330	1320
2.375			1960	1620	1530	1490	1470
2.50			2270	1820	1710	1660	1640
2.625			2630	2040	1900	1840	1811
2.75			3050	2270	2100	2030	2000
2.875				2530	2320	2230	2190
3.00				2810	2550	2440	2390
3.125				3110	2790	2670	2610
3.25				3440	3050	2900	2830
3.375				3800	3330	3150	3070
3.50				4190	3620	3410	3320
3.625				4620	3930	3690	3570
3.75				5090	4260	3980	3840
3.875				5610	4620	4280	4130
4.00				6190	4990	4600	4420
4.25					5820	5280	5050
4.50					6760	6030	5730
4.75					7840	6860	6470
5.00					9070	7780	7280
5.25					10500	8800	8150
5.50					12200	9920	9100
5.75						11200	10100
6.00						12600	11200
6.25						14100	12500
6.50						15900	13800
6.75						17800	15200
7.00						20000	16800
7.25							18500
7.50							20400
7.75							22500
8.00							24800
8.25							27400

Note: The above Flow Constants are only approximate values and should not be used in Commercial Gas Measurement Computations.

From Report No. 2, Practical Methods Committee, Appalachian Gas Measurement Short Course, School of Mines, West Virginia University, 1940.

FACTORS TO ADJUST ORIFICE METER DELIVERIES FOR SUPERCOMPRESSIBILITY—AVERAGE CONDITIONS

Gauge Press. # /sq."	0	1	2	3	4	5	6	7	8	9
0	1.0000	1.0001	1.0002	1.0003	1.0005	1.0006	1.0007	1.0008	1.0009	1.0010
10	1.0011	1.0012	1.0014	1.0015	1.0016	1.0017	1.0018	1.0019	1.0020	1.0022
20	1.0023	1.0024	1.0025	1.0026	1.0027	1.0028	1.0029	1.0031	1.0032	1.0033
30	1.0034	1.0035	1.0036	1.0037	1.0039	1.0040	1.0041	1.0042	1.0043	1.0044
40	1.0045	1.0047	1.0048	1.0049	1.0050	1.0051	1.0052	1.0053	1.0054	1.0056
50	1.0057	1.0058	1.0059	1.0060	1.0061	1.0062	1.0064	1.0065	1.0066	1.0067
60	1.0068	1.0069	1.0070	1.0072	1.0073	1.0074	1.0075	1.0076	1.0077	1.0078
70	1.0080	1.0081	1.0082	1.0083	1.0084	1.0085	1.0086	1.0088	1.0089	1.0090
80	1.0091	1.0092	1.0093	1.0095	1.0096	1.0097	1.0098	1.0099	1.0100	1.0101
90	1.0102	1.0104	1.0105	1.0106	1.0107	1.0108	1.0109	1.0111	1.0112	1.0113
100	1.0114	1.0115	1.0116	1.0117	1.0118	1.0119	1.0121	1.0122	1.0123	1.0124
110	1.0125	1.0126	1.0127	1.0128	1.0130	1.0131	1.0132	1.0133	1.0134	1.0135
120	1.0136	1.0137	1.0139	1.0140	1.0141	1.0142	1.0143	1.0144	1.0145	1.0146
130	1.0148	1.0149	1.0150	1.0151	1.0152	1.0153	1.0154	1.0156	1.0157	1.0158
140	1.0159	1.0160	1.0161	1.0162	1.0163	1.0164	1.0166	1.0167	1.0168	1.0169
150	1.0170	1.0171	1.0172	1.0174	1.0175	1.0176	1.0177	1.0178	1.0179	1.0180
160	1.0181	1.0182	1.0184	1.0185	1.0186	1.0187	1.0188	1.0189	1.0190	1.0191
170	1.0193	1.0194	1.0195	1.0196	1.0197	1.0198	1.0199	1.0200	1.0202	1.0203
180	1.0204	1.0205	1.0206	1.0207	1.0208	1.0209	1.0210	1.0212	1.0213	1.0214
190	1.0215	1.0216	1.0217	1.0218	1.0219	1.0220	1.0222	1.0223	1.0224	1.0225
200	1.0226	1.0227	1.0228	1.0229	1.0230	1.0232	1.0233	1.0234	1.0235	1.0236
210	1.0237	1.0238	1.0239	1.0240	1.0242	1.0243	1.0244	1.0245	1.0246	1.0247
220	1.0248	1.0249	1.0251	1.0252	1.0253	1.0254	1.0255	1.0256	1.0257	1.0258
230	1.0259	1.0261	1.0262	1.0263	1.0264	1.0265	1.0266	1.0267	1.0268	1.0270
240	1.0271	1.0272	1.0273	1.0274	1.0275	1.0276	1.0277	1.0279	1.0280	1.0281
250	1.0282	1.0283	1.0284	1.0285	1.0286	1.0287	1.0288	1.0290	1.0291	1.0292
260	1.0293	1.0294	1.0295	1.0296	1.0297	1.0298	1.0299	1.0300	1.0302	1.0303
270	1.0304	1.0305	1.0306	1.0307	1.0308	1.0309	1.0310	1.0311	1.0313	1.0314
280	1.0315	1.0316	1.0317	1.0318	1.0319	1.0320	1.0321	1.0323	1.0324	1.0325
290	1.0326	1.0327	1.0328	1.0329	1.0330	1.0331	1.0332	1.0333	1.0335	1.0336
300	1.0337	1.0338	1.0339	1.0340	1.0341	1.0342	1.0343	1.0344	1.0346	1.0347
310	1.0348	1.0349	1.0350	1.0351	1.0352	1.0353	1.0354	1.0355	1.0357	1.0358
320	1.0359	1.0360	1.0361	1.0362	1.0363	1.0364	1.0365	1.0366	1.0368	1.0369
330	1.0370	1.0371	1.0372	1.0373	1.0374	1.0375	1.0376	1.0378	1.0379	1.0380
340	1.0381	1.0382	1.0383	1.0384	1.0385	1.0386	1.0387	1.0389	1.0390	1.0391
350	1.0392	1.0393	1.0394	1.0395	1.0396	1.0397	1.0398	1.0399	1.0401	1.0402
360	1.0403	1.0404	1.0405	1.0406	1.0407	1.0408	1.0409	1.0410	1.0412	1.0413
370	1.0414	1.0415	1.0416	1.0417	1.0418	1.0419	1.0420	1.0421	1.0423	1.0424
380	1.0425	1.0426	1.0427	1.0428	1.0429	1.0430	1.0431	1.0433	1.0434	1.0435
390	1.0436	1.0437	1.0438	1.0439	1.0440	1.0441	1.0443	1.0444	1.0445	1.0446
400	1.0447	1.0448	1.0449	1.0450	1.0451	1.0452	1.0453	1.0454	1.0455	1.0456
410	1.0457	1.0459	1.0460	1.0461	1.0462	1.0463	1.0464	1.0465	1.0466	1.0467
420	1.0468	1.0469	1.0470	1.0471	1.0472	1.0474	1.0475	1.0476	1.0477	1.0478
430	1.0479	1.0480	1.0481	1.0482	1.0483	1.0484	1.0486	1.0487	1.0488	1.0489
440	1.0490	1.0491	1.0492	1.0493	1.0494	1.0495	1.0496	1.0498	1.0499	1.0500
450	1.0501	1.0502	1.0503	1.0504	1.0505	1.0506	1.0507	1.0509	1.0510	1.0511
460	1.0512	1.0513	1.0514	1.0515	1.0516	1.0517	1.0518	1.0520	1.0521	1.0522
470	1.0523	1.0524	1.0525	1.0526	1.0527	1.0528	1.0529	1.0530	1.0532	1.0533
480	1.0534	1.0535	1.0536	1.0537	1.0538	1.0539	1.0540	1.0542	1.0543	1.0544
490	1.0545	1.0546	1.0547	1.0548	1.0549	1.0550	1.0552	1.0553	1.0554	1.0555
500	1.0556									

Note:—Factors taken from C. N. G. A. Bul. TS-354 based on a gas having a specific gravity of .660 and an average flowing temperature of 50° F. CAUTION:—If conditions vary materially from 50° F. and 0.66 specific gravity, compute F_{pv} for actual temperature and specific gravity by reference to Bulletin T. S. 402 of C. N. G. A.—as an example: F_{pv} of 1.050 from above table may be in error by 0.01, or more, if temperature is outside range of 25° F. to 85° F. or if specific gravity is outside range of 0.605 to 0.705.

From Report No. 4, Practical Methods Committee, Appalachian Gas Measurement Short Course, School of Mines, West Virginia University, 1950.

GAS ODORANTS—CHARACTERISTICS

INFORMATION FURNISHED BY THE SEVERAL MANUFACTURERS

	Natural Gas Odorizing Co., Inc.	Oronite Chemical Company				Sharples Chemicals Inc.			
Odorant Characteristic	Captan	Calodorant	Calodorant "C"	Calodorant "C" Special	"Alert"	Pentalarm No. 86	Pentalarm No. 1004	No. 1009E (By-Pass Type)	No. 1008E (Injection Type)
Specific Gravity	.835	0.78	1.0	0.88	0.83	0.83	0.84	0.809	0.827
Molecular Weight			88	104		104		88	82
Weight per Gallon Pounds	7.0	6.5	8.34	7.31	6.9	7.0	7.0	6.74	6.9
Viscosity at 77° F Centistokes	0.548 at 60° F	0.70	0.94	0.82	0.48	0.66 Centipoise at 76° F	0.65 Centipoise at 30° F	0.642 Centipoise at 77° F	0.525 Centipoise at 77° F
Reid Vapor Pressure (At 100° F)	5.0	3.0	1.0	1.3	3.0	1.0	8.8	4.9	5.33
Distillation	Start 125° F 95% 265° F End 340° F	50% Recovered 230° F 90% Recovered 309° F End 360° F	Start 237° F End 263° F	Start 200° F End 360° F	Start 112° F End 280° F	Start 212° F 95% 266° F	Start 95° F 90% 240° F End 280° F	IBP—120° F 95% 180° F	IBP—120° F 95% 270° F
Volatility LGs/M°CF						30 lbs/MMCF at 0° F and 300 psi			
Freezing Point			−102° C			−70° F	−50° F	Below 0° F	Below 0° F
Flash Point Open Cup		−29° F	64° F			50° F			
Thermal Decomposition Temperature		800° F	900° F	800° F					
Mercaptan Content	94%					90%		94%	94%
Sulphur Content								34	37
Per Cent by weight	33		36.8			31	34		
Toxicity at Normal Concentration		none	none	none	none	none	none	none	none
Solubility in Water									
Per Cent by volume		.05	.07	.06	slight	insoluble		40% at 77° F	56% at 77° F
Recommended odorizing rate	0.25 to 1.0 lb per MMCF	13 lbs per MMCF	0.5 lb per MMCF	1.0 lb per MMCF	1.0 lb per MMCF	1.0 lb per MMCF	1.0 lb per MMCF	0.5 lb per MMCF	0.5 lb per MMCF
Sulphur Contribution at Rec. Rate. Grains per 100 Cu Ft		0.41	0.12	0.14	0.27	0.215	0.27	0.12	0.13

REFORMED NATURAL GAS

Estimated Comparative Gas Production Data Using Natural Gas for Production of a 530-Btu Finished Gas for Interchange with .67 Sp. Gr. Carburetted Water Gas Using Natural Gas of 1030-Btu and .61 Sp. Gr.

Type of Production	Blue Gas Cold-Enriched with Natural Gas	Fuel Bed Reformed Gas Cold-Enriched with Natural Gas	U.G.I. Cyclic Catalytic Reformed Gas Cold-Enriched with Natural Gas
Apparatus Used			
Mech. Gen. C.W.G. Set	9'IDx12'x12'	9'IDx12'x12'	12'x12'
Dia. Carb. and Superh	10' ID	10' ID	10' ID
Base Gas			
Specific Gravity	.58	.63	.60
Heating Value Btu/cu ft ..	280	390	266
Lb of Coke/Mcf	33.0	9.0	0
Cu ft of Natural Gas/Mcf	0	308	340
Make Per Set Day - Mcf ..	6,500	10,300	11,500
Finished Gas			
Specific Gravity	.59	.62	.61
Heating Value Btu/cu ft ...	530	530	530
Lb of Coke/Mcf	22.0	7.0	0
Cu ft of Natural Gas/Mcf .	330	460	570
Make Per Set Day - Mcf ..	10,000	13,200	17,500
Comparative Costs-Cents/Mcf of Finished Gas			
Materials			
Coke @ $16 per ton	17.6	5.6	0
Nat. Gas @ 30 cents/Mcf	9.9	13.8	17.1
	27.5	19.4	17.1
Coke @ $17.50 per ton ..	19.2	6.1	0
Nat. Gas @ 40 cents/Mcf	13.2	18.4	22.8
	32.4	24.5	22.8
Savings in Other Production Costs			
Savings - U.G.I. C.C.R. Process Over Fuel Bed Reform. in Oper. Labor, Maint., etc. - cents/Mcf .			1.0 to 2.0
Total Estimated Savings			
Total Est. Savings - U. G. I. C. C. R. Process Over Fuel Bed Reforming - cents/Mcf			3.0 to 4.0

NOTE: For an 11-ft hand-clinkered set, the fuel consumption for the base gas (blue gas) should be raised from 33 to 35 lbs and for the thermal reforming from 9 to 10 lbs.

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ANALYSES OF COAL TYPES FREQUENTLY USED IN, OR SUITABLE FOR BY-PRODUCT COKE OVENS[1]

Name of coal	Proximate analysis (on coal as received)				Ultimate analysis (on dry coal)					Btu value (dry coal)	Estimated coke yield (total), per cent on coal as received	Estimated gas yield, Btu in gas per lb coal
	Moisture	Volatile matter	Fixed carbon	Ash	Carbon	Hydrogen	Oxygen	Sulphur	Nitrogen			
Pennsylvania:												
Connellsville[2]	2.40	31.00	61.38	7.22	78.50	4.67	6.82	0.97	1.62	14,230	71.0	3,100
Lower Connellsville	2.00	32.20	58.00	7.80	77 80	5.20	6.33	1.09	1.63	14,100	70.0	3,200
Westmoreland	1.00	35.00	57.60	6.40	79.60	5.36	6.14	0.90	1.60	14,320	68.0	3,350
Pittsburgh[2]	3.03	35.22	55.36	6.39	79.45	5.34	5.94	1.23	1.45	14,230	68.5	3,300
Freeport[2]	2.66	34.35	56.42	6.57	79.13	5.34	6.18	1.02	1.58	14,180	69.0	3,300
Somerset (Orenda)[2]	3.77	16.26	71.06	8.91	81.96	4.15	2.22	0.81	1.60	14,075	81.0	2,600
Clearfield—Cambria (Lower Kittanning)[2]	2.00	21.17	70.90	5.93	84.10	4.60	2.72	1.23	1.42	14,800	78.5	2,680
West Virginia:												
Boomer[2]	2.96	33.57	59.18	4.29	82.45	5.32	5.36	0.80	1.65	14,840	69.0	3,300
Cabin Creek (Kanawha)	2.70	31.30	59.79	6.21	80.38	4.69	6.79	0.59	1.17	14,600	71.0	3,300
No. 2 gas[2]	2.52	34.86	56.42	6.20	80.86	5.15	5.16	0.87	1.60	14,500	69.0	3,300
Fairmont[2]	2.51	37.66	53.25	6.58	78.63	5.29	6.56	1.23	1.54	14,130	66.0	3,350
Pocahontas[2]	2.60	16.39	76.38	4.63	86.79	4.22	2.33	0.78	1.13	15,020	81.0	2,650
New River[2]	3.51	24.76	69.00	2.73	86.08	4.95	3.91	0.60	1.63	15,220	75.0	2,750
Elkins[2]	1.40	26.40	62.92	9.28	79.03	4.74	3.85	1.52	1.45	14,020	75.0	2,850
Virginia:												
Tasewell Co. (Seaboard)[3]	3.13	29.00	61.77	6.10	82.63	4.82	4.23	0.60	1.42	14,670	71.0	3,100
Toms Creek[3]	2.29	32.87	59.62	5.22	82.67	5.05	4.78	0.55	1.61	14,810	70.0	3,200
Wise Co. (Roda)	2.00	34.90	60.90	2.20	84.50	5.27	5.85	0.55	1.63	14,990	69.0	3,300
Eastern Kentucky:												
Elkhorn[3]	2.91	36.33	57.53	3.23	82.26	5.49	6.71	0.57	1.64	14,650	66.0	3,450
Coxton[3]	3.18	37.21	56.30	3.31	81.50	5.30	7.10	0.96	1.72	14,620	65.0	3,450
Benham[3]	2.50	37.52	57.63	2.35	83.01	5.42	7.07	0.53	1.56	14,960	65.5	3,500
Tennessee:												
Jellico[3]	3.87	38.03	55.18	2.92	80.34	5.54	7.90	1.13	2.05	14,250	63.0	3,400
Alabama:												
Pratt Seam[2]	2.20	28.83	62.88	6.09	81.69	4.97	3.86	1.66	1.59	14,550	72.0	3,000
Tuscaloosa[2]	2.62	24.18	64.11	9.09	79.61	4.55	4.33	0.66	1.52	14,090	75.0	2,700
Illinois:												
Franklin Co. (Orient)[3]	9.93	33.13	48.77	8.17	74.47	4.84	9.22	0.83	1.57	13,200	61.0	2,900
Indiana:												
Ayrshire[3]	12.31	35.05	46.54	6.10	75.87	5.19	9.15	1.11	1.72	13,530	60.0	2,950
Colorado:												
Trinidad[3]	4.29	36.51	52.03	7.17	77.24	5.12	8.09	0.61	1.45	13,670	64.0	3,150
Utah:												
Sunnyside[3]	4.06	37.99	49.89	8.06	74.95	5.43	8.49	1.20	1.53	13,380	63.0	3,200
Washington:												
Roslyn	3.77	37.09	47.05	11.49	72.92	5.36	7.71	0.49	1.58	13,262	63.0	3,100

Most of these analyses except where noted are of face samples taken in the mine; usually car deliveries to to the consumer run 2% to 3% higher in ash.

[1] Prepared by Dr. H. C. Porter, Consulting Engineer, Philadelphia.
[2] Mine sample, analysis by U.S. Bureau of Mines.
[3] Car sample, average of 10 cars, analysis by U.S. Bureau of Mines.

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ANALYSES OF SELECTED COALS OF VARIOUS RANKS

"As received" basis

Rank*	State	Seam	Proximate analysis, %				Ultimate analysis, %					Heating value, B.t.u./lb.
			Moisture	Volatile matter	Fixed carbon	Ash	Carbon	Hydrogen	Oxygen	Sulfur	Nitrogen	
Anthracitic:												
Meta-anthracite	Rhode Island	Uncorrelated	1.0	4.0	66.7	28.3	...	..	...	..	..	9,620
Anthracite	Pennsylvania	Mammoth	2.3	3.1	87.7	6.9	86.7	2.2	2.9	0.5	0.8	13,540
Anthracite	Pennsylvania	Big Lykens	2.1	7.5	80.3	10.1	80.9	3.3	4.2	0.5	1.0	13,480
Semianthracite	Virginia	Merrimac	2.2	12.4	67.4	18.0	72.4	3.6	4.7	0.5	0.8	12,270
Bituminous:												
Low-volatile	West Virginia	Pocahontas No. 3	3.5	18.2	74.4	3.9	84.0	4.8	5.6	0.6	1.1	14,550
Medium-volatile	West Virginia	Sewell	3.1	25.0	66.8	5.1	...	..	...	1.3	..	14,290
High-volatile A	Pennsylvania	Pittsburgh	2.6	30.0	58.3	9.1	76.6	5.2	6.2	1.3	1.6	13,610
High-volatile A	Kentucky	Elkhorn	3.1	35.0	58.9	3.0	79.2	5.7	10.0	0.6	1.5	14,290
High-volatile B	Ohio	Middle Kittanning	8.2	36.1	48.7	7.0	68.4	5.6	16.4	1.2	1.4	12,160
High-volatile B	Kentucky	No. 6	7.2	39.8	48.8	4.2	71.5	5.8	14.3	2.6	1.6	12,950
High-volatile C	Illinois	No. 2	12.1	40.2	39.1	8.6	62.8	5.9	17.4	4.3	1.0	11,480
High-volatile C	Indiana	No. 6	12.4	36.6	42.3	8.7	63.4	5.7	18.6	2.3	1.3	11,420
Subbituminous:												
Subbituminous A or high-volatile bituminous C	Wyoming	Uncorrelated	16.5	34.2	38.1	11.2	...	..	...	2.1	..	9,740
Subbituminous B	Wyoming	Monarch	23.2	33.3	39.7	3.8	54.6	6.4	33.8	0.4	1.0	9,420
Subbituminous C	Wyoming	Uncorrelated	24.6	27.7	39.9	7.8	...	..	...	1.1	..	8,610
Lignitic:												
Lignite	North Dakota	Beulah	34.8	28.2	30.8	6.2	42.4	6.7	43.3	0.7	1.7	7,210

*According to A.S.T.M. method of classification.

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OPERATING RESULTS, BY-PRODUCT COKE OVENS[1]

	Utica	Philadelphia
Coal used, per cent volatile matter (ash- and moisture-free)[2]	37.8	30.1
Coal charge, tons	6.86	17.9
Coking time (average), hr (gross)	12.6	16.46
Width of ovens (average), in.	13½	17¼
Coke yield, per cent dry	70.2	74.0
Gas, cu ft per lb dry coal	5.66	5.36
Gas, Btu per cu ft	584	577
Gas, Btu per lb dry coal	3,305	3,093
Producer fuel, dry, per ton coal, lb	292	215
Producer fuel, combustible, per ton coal, lb	253	200
Producer fuel used, cu ft per lb coal (at 130 Btu)	9.99	7.52
Yield tar, gal per ton	12.35	8.16
Yield sulphate, lb per ton	24.68	20.92 (Diluted with 11% producer gas)
Gas analysis:		
CO_2, per cent	2.2	1.8
Ill., per cent	4.0	3.3
O_2, per cent	0.8	0.3
CO, per cent	6.3	8.5
CH_4, per cent	32.1	24.7
H_2, per cent	46.5	51.0
N_2, per cent	8.1	10.4
	100.0	100.0

Data assembled by H. C. Porter, Philadelphia.

[1] Actual plant data submitted by The Koppers Company, Pittsburgh, Pa., for two plants, Utica, N. Y. (consisting of 21 small-size ovens built in 1924), and Philadelphia, Pa. (consisting of 74 large-size ovens built in 1928), both plants being Becker type Koppers ovens, fired by producer gas. The Utica results are taken from the official report of A. G. A. Carbonization Plant Tests made in 1925 for comparison of different types of plant, operating on the same coal. The Utica ovens were the first of their size and type to be built and on that account were not operating at the time to the best advantage. The Utica results cover a period of 21 days. The Philadelphia results are averages for a five-month period.

[2] At Utica, 100 per cent volatile Pittsburgh coal; at Philadelphia a mixture averaging 76 per cent Powellton (W. Va.) and 24 per cent Pocahontas.

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PRODUCTS OF HI AND LOW TEMPERATURE CARBONIZATION

Yields of High Temperature, Low Temperature and Complete Gasification Processes

Process	Yield Ammonium Sulphate	Yield Light Oil Benzol Tobol, Xylol	Yield Tar	Yield Gas	Yield Coke
High Temperature Distillation	20–24 lbs. Per Ton	3 plus gals. Per Ton	8–12 gals. Per Ton	10,000–11,500 Cu.Ft. Per Ton 500–560 Btu Per Cu.Ft.	1300–1400 lbs. Per Ton Suitable for Metallurgical Processes and Domestic Fuel
Low Temperature Distillation	16–20 lbs. Per Ton	3–5 gals. Per Ton	20–28 gals. Per Ton	5000–6000 Cu.Ft. Per Ton 500 to 900 Btu Per Cu.Ft.	1400 lbs. plus Per Ton Domestic Fuel May have to be briquetted
Complete Gasification	75 lbs. Per Ton	1 gal. plus Per Ton	25 gals. Per Ton	100,000 Cu.Ft. plus Per Ton Below 200 Btu's Per Cu.Ft.	None

BULK DENSITY OF COAL AND COKE

(Spiers, Technical Data on Fuel)

Fuel	Bulk Density (Pounds per cu. ft.)	
Anthracite	55—60	
Bituminous Coal	50—55	
Steam Coal	50—55	
	¾—1½ In.	Rough
Coke oven coke	26—30	29—32
Horizontal coke	23—26	25—28
Vertical coke	21—22	23
Low temperature coke	19	20

Data refer to fuel broken ready for use and of normal ash and moisture content.

CALCULATING HEATING VALUE OF COAL FROM ANALYSIS

By far the most satisfactory way of determining the heating value of a coal is by the bomb calorimeter. Where only the analysis is available the following computations of the approximate heating value of the coal may be made.

Ultimate Analysis:

$$\text{B.t.u. per lb.} = 146\ C + 620\ (H - \frac{O}{8}) + 40.5\ S$$

where

C = per cent of carbon.
H = per cent of hydrogen.
O = per cent of oxygen.
S = per cent of sulphur.

With bituminous and anthracite coals the calculated values will usually be within 1½ per cent of the observed value. The higher the percentage of oxygen the greater is the error apt to be.

Proximate Analysis:

B.t.u. per lb. = (C × c + V × v)—(16 M + 30 A + 39 S) where

C = per cent of fixed carbon.
V = per cent of volatile combustible.
M = per cent of moisture.
A = per cent of ash.
S = per cent of sulphur.
c — see Table I.
v — see Table II.

Table I
Values of c.

For Anthracite Coal	141
For Bituminous Coal	140
For Lignite	95
For Coke	130

Table II
Values of v.

Per Cent Vol. Comb.	"v"	Per Cent Vol. Comb.	"v"
1	240.5	27	180.5
2	236.4	28	178.8
3	232.5	29	177.2
4	228.8	30	175.5
5	225.3	31	173.9
6	221.9	32	172.3
7	218.6	33	170.7
8	215.4	34	169.2
9	212.3	35	167.8
10	210.3	36	166.6
11	208.3	37	165.5
12	205.4	38	164.4
13	204.6	39	163.3
14	202.7	40	162.2
15	200.9	41	161.1
16	199.2	42	160.0
17	197.5	43	158.9
18	195.7	44	157.8
19	194.0	45	156.7
20	192.3	46	155.6
21	190.6	47	154.5
22	188.9	48	153.4
23	187.2	49	152.3
24	185.5	50	151.2
25	183.8	51	150.1
26	182.1	52	149.0

H. H. Clark—American Gas Light Journal.

Purifier Reactions

(1) $Fe_2O_3 \cdot H_2O + 3H_2S = Fe_2S_3 + 4H_2O$.
(2) $Fe_2O_3 \cdot H_2O + 3H_2S = 2FeS + S + 4H_2O$.

Revivification of fouled oxide:

(3) $2Fe_2S_3 + 3O_2 + 2H_2O = 2Fe_2O_3 \cdot H_2O + 6S$.
(4) $4FeS + 3O_2 + 2H_2O = 2Fe_2O_3 \cdot H_2O + 4S$.

Purifier reaction (1) is the desirable one in gas purification. It occurs under alkaline conditions. The ferric sulphide (Fe_2S_3) is readily converted back to the hydrate oxide with oxygen in the presence of suitable amounts of moisture according to reaction (3).

Purification reaction (2) takes place under neutral or slightly acid conditions. The ferrous sulphide (FeS) may also be oxidized to hydrated ferric oxide according to the equation (4). The formation of ferrous sulphide is undesirable because at slightly elevated temperatures, caused by the heat given off in the reaction between oxide and H_2S, the ferrous sulphide combines with free sulphur forming iron disulphide. FeS_2 as follows:

(5) $FeS + S = FeS_2$

FeS_2 is inert and is not reoxidized to hydrated oxide. At 100° F. ferrous sulphide is oxidized to ferrous sulphate:

(6) $FeS + 2O_2 = FeSO_4$

Ferrous sulphate in the presence of water reacts acid. To correct this condition some manufacturers of purification material request that the plants submit a gallon sample of the fouled oxide for a complete analysis immediately after it has been discharged from the box. If the oxide is found to be sour, in other words less than a pH of 7, it is recommended that slacked lime be forked into the material before recharging it into the box. Also from the contaminate content of the oxide it can be determined whether naphthalene, cyanogen, light oils and tars are being properly removed by the gas cleaning equipment. Finally, the amount of combined sulphur present in the sample indicates whether sufficient air is being added to the gas for revivification *in situ*.

Types of "Oxide"

There are three types of oxide used for gas purification. They are Natural Iron Ores, Rusted Cast Iron Borings and Precipitated Oxides.

Capacity of Purifiers

The primary factors in purifier capacity are: time of contact and the amount of H_2S in the unpurified gas.

There are several rules or formulas for calculating purifying capacity. Some specify so many square feet of cross sectional area per unit volume of gas passed in a given time, others include the depth of oxide. A formula which allows for the several factors is the Semet-Solvay Formula, shown here.

Less complicated rules are those given by E. L. Sweeney, G. E. Seil and T. P. Keller.

Sweeney recommends a purifier capacity of 5,000 bushels of active oxide, or 6,000 bushels of normal oxide per million cu. ft. of maximum day output.

Seil says that it is customary to figure on 5 bushels of oxide sponge per 1000 cu. ft. of gas per day, which is substantially the same as Sweeney's recommendation.

Keller suggests purifier capacity based on 30 cu. ft. of gas per hour per bushel of oxide in each box, and recommends no less than a 4 box series in any plant operating continuously. However, in a plant where the gas temperature moisture, cleaning and other conditions are favorable, the quantity of gas handled may be as high as 100 cu. ft. per hour per bushel per box.

Miscellaneous Notes

Clean gas and clean oxide are essential to efficient purification.

Selection of oxide is largely a local matter, as there are many suitable oxides from which one may choose. The main considerations are:

1. The material should contain no metallic iron or steel and the mass should be easily permeable to the gas.
2. The concentration of iron oxide may vary from 5 pounds to 15 pounds Fe_2O_3 per bushel, depending upon local conditions.
3. Care should be taken that the oxide does not take fire or be violently heated.
4. Do not allow oxide to dry out while lying around or in the boxes. Once it becomes too dry, it is difficult to get the material to absorb the proper amount of moisture.

The activity of oxide increases with an increase in temperature. A temperature range of from 92° to 100° F. is very satisfactory. For proper removal of tar and oils it is advantageous to cool the gas to 60° F. or lower. If the gas reaches the purifiers at a temperature of 60° F. or lower, the temperature can be easily raised to 92° F. or 100° F. by introducing steam into the gas at the inlet to the purifiers. This will saturate the gas at the higher temperatures and prevent drying the oxide. At a temperature of 60° F. most oxides are quite active and if the oxide is clean it will ultimately remove more sulphur even at 40° or 50° F. than material saturated with tar.

When oxide throws excessive back pressure, one remedy is to take off the cover of the box and remove the impervious crust. This can only be accomplished when the gas flow is in at the top and out at the bottom, and is one reason why it is distinctly advantageous to have one directional gas flow. Likewise in down

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SEMET-SOLVAY ENGINEERING CORPORATION GAS PURIFIER FORMULA BASED ON ORIGINAL STEERE ENGINEERING COMPANY FORMULA

$$2A = \frac{G \times S}{3{,}000 \times (D + C)}$$

$$G = \frac{3{,}000 \times (D + C) \times A}{S}$$

Where G = maximum quantity of gas in cubic feet (corrected to 60° F.) to be purified per hour.

S = factor for grains of hydrogen sulphide (H_2S) per 100 cu. ft. of unpurified gas, as given in the table below.

D = ½ the total depth in feet of oxide through which the gas passes consecutively in the purifier set, and is abtained by multiplying the depth of such oxide per box by the number of boxes in series in the set. Where a single "catch box" is used for two or more sets, disregard the catch box in obtaining factor "D."

A = cross sectional area in square feet of the oxide through which the gas passes on its way through any one box, in series of a set.

C = factor, 4 for two-box, 8 for three-box, and 10 for four-box series, respectively. Where a single catch box is used for two two-box sets, use factor C = 6.

3,000 = assembling constant.

Factor corresponding to the value of S expressed in grains H_2S per 100 cu. ft. unpurified gas is:

Grains	Factor
1,000 or more	720
900	700
800	675
700	640
600	600
500	560
400	525
300	500
200 or less	480

flow boxes any deposition of moisture is more evenly distributed when the moisture is draining from the box in the direction of the gas flow and not counter current to it. Where an impervious layer cannot be partially removed, it is necessary to dump the entire box.

Most oxide manufacturers will furnish oxide of various degrees of coarseness dependent upon whether the local plant condition necessitates special material due to dry gases or to tar contaminated gas.

When new or comparatively new oxide is removed from the box, it must never be left in piles, but should be spread out in a layer from 12″ to not over 18″ deep; otherwise it may take fire. The purifier should be completely emptied and no oxide left in it over night.

The alkalinity of oxide is important for efficient purification. New material should be sufficiently alkaline to show a pH value of from 8 to 11 when put in the boxes. A pH value of 7 or more should be maintained during the total life of the material. If the alkalinity goes below 7, sulphur and iron will combine to form a compound that will not revive. Alkalinity can be maintained by adding 4 to 6 grains of ammonia per thousand cubic feet in carburetted water gas or 10 grains per thousand cubic feet of coke oven gas where cyanogen compounds do not exceed 40 grains per hundred cubic feet. Under certain conditions oxide manufacturers will recommend the addition of a wetting agent and sufficient alkali by means of a spray in the box in order to maintain an alkaline pH throughout the life of the oxide.

There are numerous inexpensive pH sets on the market so that the smallest gas plant can purchase one for not only the control of their purifying boxes, but also for their boiler water determinations.

E. L. Sweeney (A.G.A. Production Conference 1939, published in *American Gas Journal* 1939) gives the following additional notes on dry box purification.

"For economical operation a capacity of 5000 bushels of active oxide; or 6000 bushels of normal oxide, per million cubic feet of maximum day output is satisfactory.

"A flow of gas equivalent to 30-50 cu. ft. per hour per bushel of oxide in the first box is desirable. The rate of flow should be as high as possible. It depends upon the kind of oxide used and the concentration of H_2S. If the material is of normal activity, a rate as high as 50 cu. ft. per hour per bushel of oxide in the first box can be used. A rate below 30 cu. ft. will, in most cases, eventually result in traces of H_2S passing the system. This phenomenon is more than likely due to the thickness of the water and gas film on the surface of the oxide particles which is affected by the velocity of the gas. The diffusion rate of H_2S through this film is the controlling factor.

"A mixture of approximately 2 volumes of carrier to 1 volume of ore produces a satisfactory surface area.

"The concentration of oxygen in the outlet gas should be 0.5%-1.0%.

"The activity of an oxide increases with increase of temperature and a range between 90°-110° F. controlled with exhaust or live steam injected into the inlet gas main has been found satisfactory.

"A rise in temperature through the system usually indicates either excess oxygen, or a deficiency in moisture, sometimes both. This condition will cause the oxide to become caked, dry and inactive, except in a few instances where the gas entering is saturated and the interval of time between dumping is comparatively short.

LEAD ACETATE TEST FOR HYDROGEN SULPHIDE

The gas shall be considered free from hydrogen sulphide (H_2S) if a strip of white paper, moistened with a solution containing per cent by weight of lead acetate, is not distinctly darker than a second paper freshly moistened with the same solution, after the first paper has been exposed to the gas for 1 minute in an apparatus of approved form, through which the gas is flowing at the rate of approximately 5 cu. ft. per hour, the gas not impinging directly from a jet upon the test paper.

Bureau of Standards, Circ. 32.

SENSITIVE BASIC ACETATE

50 grams of lead acetate per liter made basic with NaOH until the precipitate first formed is dissolved. This solution stains light brown at a concentration of less than 0.04 grains of H_2S per 100 cu. ft. It is about 10 times as sensitive as the standard lead acetate paper tests.

E. L. Sweeney.

GIRBOTOL PROCESS: THEORY AND DESCRIPTION

The Girbotol process originated with the discovery that acidic gases such as hydrogen sulphide and carbon dioxide react with certain amines to form compounds which may be dissociated by heat. The reactions between a primary amine and hydrogen sulphide are as follows:

$2RNH_2 + H_2S \leftrightarrows (RNH_3)_2S$—Amine sulphide
$(RNH_3)_2S + H_2S \leftrightarrows 2RNH_2HS$ Amine hydrosulphide

These reactions are reversible, the equilibria depending upon the concentrations of the reactants and the temperature. The reactions between amines and carbon dioxide are analogous to those with hydrogen sulphide.

The amines are organic bases, derivatives of ammonia; and, like ammonia, react rapidly with acids such as hydrogen sulphide and carbon dioxide to form salts. Until a high percentage of the available amine has been neutralized, the resulting solution has a negligible acidgas vapor pressure. By carrying out the absorption counter-currently, the acidic component of a gas stream may be stripped out completely.

A number of amines suitable for use in the Girbotol process are available commercially at reasonable cost. Since each differs slightly in its physical properties from the others, there is a group of absorbents from which the proper amine may be selected for any particular purification plant. All of the amines which are used have the desirable characteristics of high capacity for the acid gas which is to be absorbed, rapid rate of reaction, and low volatility. These amines are miscible with water in all proportions, but are substantially insoluble in hydrocarbons. Due to their high capacities for acidic gases, dilute water solutions may be circulated and because of their low volatility no appreciable amount of reagent is lost into the scrubbed product.

Because of the ease with which acidic gases are liberated from the amines at elevated temperatures (212°F. and above), the regeneration of these solutions can be effected economically. It can be accomplished by boiling the amine solution in a simple evaporator or pot still. However, the use of a packed or bubble tray column reduces the steam consumption materially. Low steam usage results in a correspondingly low cooling water requirement.

Improved reactivation and selective reactivation between hydrogen sulphide and carbon dioxide can be accomplished by carrying out the regeneration step at super-atmospheric pressure.

The Girbotol absorbents in themselves are not corrosive toward steel or iron, and when proper precautions are taken in the design and operation of Girbotol plants, corrosion is not encountered. Because the Girbotol solutions are alkaline, the corrosive effect of hydrogen sulphide and carbon dioxide are negligible. Low carbon steel and cast iron are suitable construction materials for all portions of Girbotol plants.

AVERAGE PROPERTIES OF LIQUEFIED PETROLEUM GAS PRODUCTS

	Commercial Propane	Industrial Propane	Commercial Butane
Vapor Pressure Lbs./Sq. In. Gauge			
at 70° F.	124	122	31
at 100° F.	192	190	59
at 105° F.	206	204	65
at 130° F.	286	282	97
Specific Gravity of Liquid (60°/60° F.)	0.509	0.511	0.582
Initial Boiling Point at 14.7 Lbs./Sq. In. Abs., °F.	−51	−51	15
Weight per Gallon of Liquid at 60° F., Lbs.	4.24	4.26	4.84
Dew Point at 14.7 Lbs./Sq. In. Abs., °F.	−46	−45	24
Specific Heat of Liquid, Btu/Lb./°F. at 60° F.	0.588	0.587	0.549
Cu. Ft. of Gas at 60° F., 30" Hg. Per Gallon of Liquid at 60° F.	36.28	36.18	31.46
Specific Volume of Gas, Cu. Ft./Lb. at 60° F., 30" Hg.	8.55	8.50	6.50
Specific Heat of Gas, Btu/Lb./°F. at 60° F. (Cp)	0.404	0.401	0.382
Specific Gravity of Gas (Air = 1) at 60° F., 30" Hg.	1.52	1.53	2.01
Ignition Temperature in Air, °F.	920-1020	920-1020	900-1000
Maximum Flame Temperature in Air, °F.	3595	3600	3615
Percent Gas in Air for Maximum Flame Temperature,-%	4.2-4.5	4.2-4.4	3.3-3.4
Maximum Rate of Flame Propagation in 25 mm. Tube:			
Cms. Per Second	84.9	85.9	87.1
Inches Per Second	33.4	33.8	34.3
Limits of Inflammability in Air, Gas Per Cent in Gas-Air Mixture:			
At Lower Limit, %	2.4	2.4	1.9
At Maximum Rate of Flame Propagation, %	4.7-5.0	4.7-4.9	3.7-3.9
At Upper Limit, %	9.6	9.6	8.6
Required for Complete Combustion:			
Cu. Ft. O_2/Cu. Ft. Gas	4.9	4.9	6.3
Cu. Ft. Air/Cu. Ft. Gas	23.4	23.4	30.0
Lbs. O_2/Lb. Gas	3.60	3.59	3.54
Lbs. Air/Lb. Gas	15.58	15.52	15.3
Products of Complete Combustion:			
Cu. Ft. CO_2/Cu. Ft. Gas	3.0	3.0	3.9
Cu. Ft. H_2O/Cu. Ft. Gas	3.8	3.8	4.6
Cu. Ft. N_2/Cu. Ft. Gas	18.5	18.5	23.7
Lbs. CO_2/Lb. Gas	3.0	3.0	3.1
Lbs. H_2O/Lb. Gas	1.6	1.5	1.5
Lbs. N_2/Lb. Gas	12.0	11.9	11.8
Ultimate CO_2, % by Volume	13.9	13.9	14.1
Latent Heat of Vaporization at Boiling Point:			
Btu per Pound	185	184	167
Btu per Gallon	785	784	808
Total Heating Values (After Vaporization):			
Btu per Cubic Foot	2522	2537	3261
Btu per Pound	21560	21570	21180
Btu per Gallon	91500	91800	102600

Phillips Petroleum Company, with permission.

SPECIFICATIONS AND TEST METHODS NGAA LIQUEFIED PETROLEUM GAS

The following specifications and test methods for liquefied petroleum gases were adopted as Tentative Standards by the Natural Gasoline Association of America, effective September 1, 1940:

Commercial Propane

DEFINITION. Commercial Propane shall be a hydrocarbon product composed predominantly of propane and/or propylene and shall be free from harmful quantities of deleterious substances.

COMPOSITION. The composition of Commercial Propane shall be at least 95 per cent propane and/or propylene by liquid volume as determined by the combined results of the Vapor Pressure and Mercury Freezing Tests.

MERCURY FREEZING TEST. The residue as determined by means of the Mercury Freezing Test shall not be more than two per cent by volume.

VAPOR PRESSURE. The vapor pressure at 105° F., as determined by the Liquefied Petroleum Gas Vapor Pressure Method shall not be in excess of 225 pounds per square inch gage pressure.

SULPHUR CONTENT. The product shall be free of hydrogen sulphide and shall not contain mercaptans, or sulphur compounds, of corrosive nature. The unstenched product shall not contain total sulphur in excess of fifteen (15) grains per hundred (100) cubic feet of vapor as determined by the test for Total Sulphur in Liquefied Petroleum Gases.

WATER CONTENT. The product shall satisfactorily pass the standard Cobalt Bromide Test.

ODORIZATION. A sufficient quantity of an odorizing agent of such character as to indicate positively the presence of gas down to concentrations in air of not over one-fifth the lower limit of flammability by a distinctive odor shall be added by the manufacturer; provided, however, that odorization is not required if harmful in the use or further processing of the liquefied petroleum gas, or if odorization will serve no useful purpose as a warning agent in such use or further processing.

Commercial Butane

DEFINITION. Commercial butane shall be a hydrocarbon product composed predominantly of butanes and/or butylenes and shall be free from harmful quantities of deleterious substances.

VAPOR PRESSURE. The vapor pressure at 105° F. as determined by the Liquefied Petroleum Gas Vapor Pressure Method, shall not be in excess of 75 pounds per square inch by gage pressure.

95 PER CENT BOILING POINT. The quantity evaporated at a temperature of 34° F., corrected to a barometric pressure of 740 mm. Hg., shall be 95% or more by volume, as determined by the Open Cylinder Weathering Test.

SULPHUR CONTENT. *Same as for Commercial Propane.*

WATER CONTENT. The product shall be free of mechanically entrained water.

ODORIZATION. *Same as for Commercial Propane.*

Butane-Propane Mixtures

DEFINITION. Butane-Propane mixtures shall be hydrocarbon products composed predominantly of mixtures of butanes and/or butylenes with propane and/or propylene and shall be free from harmful quantities of deleterious substances.

VAPOR PRESSURE. *Same as for Commercial Propane.*

PRODUCT DESIGNATION. Butane-Propane mixtures shall be designated by the vapor pressure at 100° F. in pounds per square inch gage. To comply with the designation the vapor pressure of mixtures shall be within +0 lbs. —5 lbs. of the vapor pressure specified. For example, a product specified as 95 lbs. LP-G shall have a vapor pressure of at least 90 lbs. but not exceeding 95 lbs.

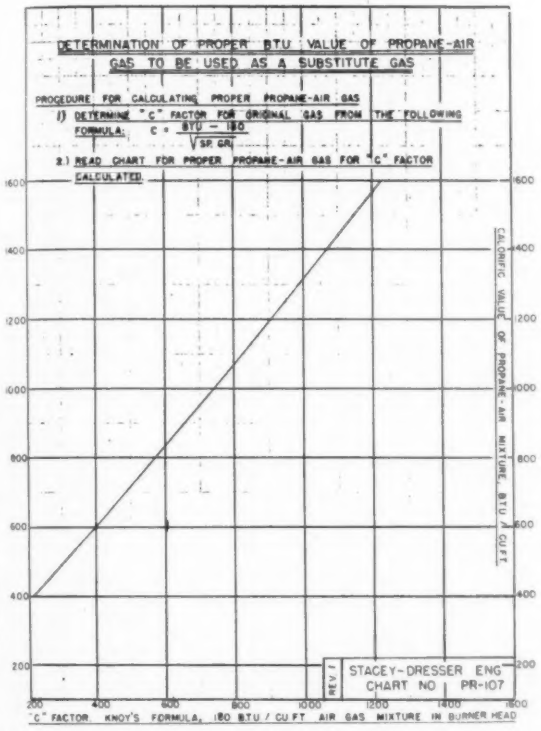
95 PER CENT BOILING POINT. *Same as for Commercial Butane.*

SULPHUR CONTENT. *Same as for Commercial Propane.*

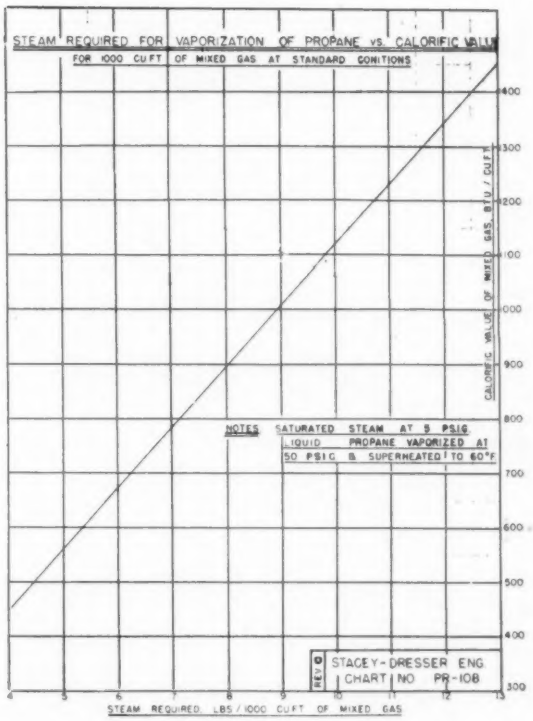
WATER CONTENT. *Same as for Commercial Butane.*

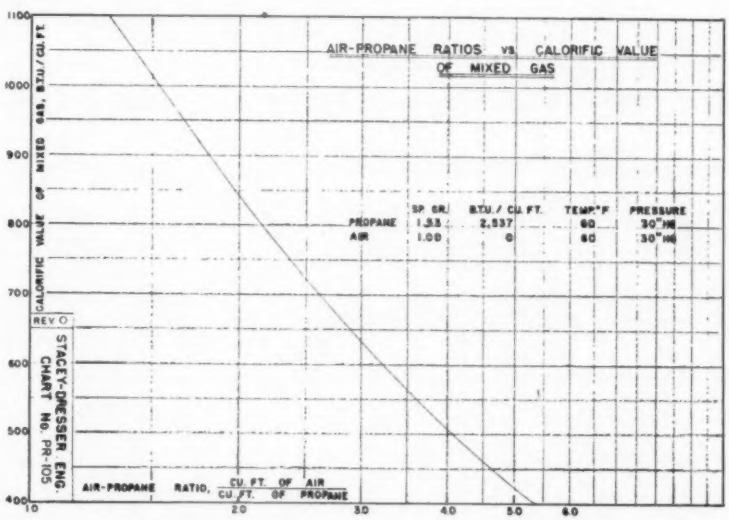
ODORIZATION. *Same as for Commercial Propane.*

KNOY'S FORMULA FOR SUBSTITUTE GAS CALCULATIONS


DETERMINATION OF PROPER BTU VALUE OF PROPANE-AIR GAS TO BE USED AS A SUBSTITUTE GAS
PROCEDURE FOR CALCULATING PROPER PROPANE-AIR GAS
1) DETERMINE "C" FACTOR FOR ORIGINAL GAS FROM THE FOLLOWING FORMULA: C = BTU − 180 / √SP. GR.
2.) READ CHART FOR PROPER PROPANE-AIR GAS FOR "C" FACTOR CALCULATED.
CALORIFIC VALUE OF PROPANE-AIR MIXTURE B.T.U./CU.FT.
REV A
STACEY-DRESSER ENG.
CHART NO. PR-107
"C" FACTOR KNOY'S FORMULA, 180 BTU / CU FT AIR GAS MIXTURE IN BURNER HEAD

STEAM REQUIRED FOR VAPORIZING PROPANE


STEAM REQUIRED FOR VAPORIZATION OF PROPANE vs. CALORIFIC VALUE
FOR 1000 CU FT OF MIXED GAS AT STANDARD CONDITIONS
CALORIFIC VALUE OF MIXED GAS, B.T.U. / CU.FT.
NOTES SATURATED STEAM AT 5 PSIG
LIQUID PROPANE VAPORIZED AT 50 PSIG & SUPERHEATED TO 60°F
REV D
STACEY-DRESSER ENG.
CHART NO. PR-108
STEAM REQUIRED, LBS / 1000 CU FT OF MIXED GAS


AIR-PROPANE RATIOS vs. CALORIFIC VALUE OF MIXED GAS
CALORIFIC VALUE OF MIXED GAS, B.T.U./CU.FT.
SP. GR. B.T.U. / CU. FT. TEMP. °F PRESSURE
PROPANE 1.53 2,537 60 30" HG
AIR 1.00 0 60 30" HG
REV O
STACEY-DRESSER ENG.
CHART No. PR-105
AIR-PROPANE RATIO, CU. FT. OF AIR / CU. FT. OF PROPANE

AIR-PROPANE RATIOS vs. CALORIFIC VALUE

PHYSICAL CONSTANTS OF PARAFFIN HYDROCARBONS—1945 N.G.A.A. Standard 2145

	METHANE	ETHANE	PROPANE	ISO-BUTANE	N-BUTANE	ISO-PENTANE	N-PENTANE	N-HEXANE	N-HEPTANE	N-OCTANE	N-NONANE	N-DECANE
Molecular Formula	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_4H_{10}	C_5H_{12}	C_5H_{12}	C_6H_{14}	C_7H_{16}	C_8H_{18}	C_9H_{20}	$C_{10}H_{22}$
Molecular Weight	16.042	30.068	44.094	58.120	58.120	72.146	72.146	86.172	100.198	114.224	128.250	142.276
Melting Point @ 14.696 Lbs./sq. in. Abs. °C.	—182.5 28	—183.2 38	—187.7 37	—159.4 55	—138.3 55	—160.6 29	—129.7 29	— 95.4 29	— 90.6 29	— 56.8 7	— 53.7 7	— 29.7 2
°F.	—296.5	—297.8	—305.9	—255.3	—216.9	—257.1	—201.5	—139.7	—131.1	— 70.0	— 64.7	— 21.5
Boiling Point @ 14.696 Lbs./sq. in. Abs. °C.	—161.4 24	— 89.0 38	— 42.1 9, 37	— 11.7 55	— 0.5 16	+ 27.9 55	36.1 6, 15	68.7 15, 8	98.4 15, 17, 35	125.7 7	150.7 7	174.0 7
°F.	—258.5	—128.2	— 43.8	+ 10.9	+ 31.1	+ 82.2	97.0	155.7	209.1	258.1	303.3	345.2
Density of Liquid Specific Gravity @ 60/60° F.	0.3** 19, 20, 21	0.374 44	0.508 41	0.563 41	0.584 23, 5, 41	0.625 12	0.631 14, 15, 41	0.664 8, 13, 34	0.688 14, 15	0.707 32	0.722 24	0.734 1
°A.P.I.	340**	247	147.0	119.8	110.8	94.9	92.7	81.6	74.2	68.6	64.5	61.3
Lb. per Gal. @ 60° F.	2.5**	3.11	4.23	4.69	4.86	5.20	5.25	5.53	5.73	5.89	6.01	6.11
Gal. per Lb. Mol @ 60° F.	6.4**	9.64	10.41	12.38	11.94	13.84	13.71	15.57	17.47	19.38	21.31	23.25
Density of Vapor 60° F. 14.696 Lbs./sq. in. Abs.***												
Specific Gravity (Air = 1.00)	0.554	1.038	1.522	2.006	2.006	2.491	2.491	2.975	3.459	3.943	4.428	4.912
Lb./M Cu Ft.	42.27	79.23	116.2	153.1	153.1	190.1	190.1	227.1	264.0	301.0	337.9	374.9
Cu. Ft. Vapor/Gal. Liq.	59**	39.35	36.45	30.65	31.79	27.41	27.67	24.38	21.72	19.58	17.81	16.32
Ratio, Gas Vol./Liq. Vol.*	443**	294.3	272.7	229.3	237.8	205.0	207.0	182.4	162.5	146.5	133.2	122.1
Critical Conditions Temperature—°C	— 82.5 24	+ 32.3 39, 36	96.8 30	134.0 24	152.0 39	187.8 24	197.2 24	234.8 24	267.0 17	296.0 24	322.2 33	346.1 38
Temperature—°F	—116.5	+ 90.1	206.2	273.2	305.6	370.0	387.0	454.6	512.6	564.8	612.0	655.0
Pressure—Atmospheres	45.8 24	48.2 39	42.0 30	36.1 2	37.5 39	32.8 24	33.0 24	29.5 24	27.0 17	24.6 24	22.9 33	21.2 33
Pressure—Lb./Sq In Abs.	673	708	617	530	551	482	485	434	397	361	337	312
Density Lb./Gal.	1.351 25	1.695 39	1.888 25	1.946 25	1.891 39	1.955 25	1.935 25	1.958 25	1.957 25	1.942 52	1.935 54	1.919 54
Volume, Cu. Ft./Lb. Mol.	1.586	2.371	3.123	3.990	4.130	4.930	4.98	5.88	6.84	7.86	8.86	9.91
Gross Heat of Combustion B.T.U./Lb Vapor*	23,920 3	22,350 3	21,690 3	21,290 5	21,340 3	21,060 40	21,120 3	20,970 3	20,860 3	20,780 3	20,710 3	20,660 3
B.T.U./Cu. Ft.*	1,011	1,771	2,521	3,259	3,267	4,003	4,015	4,762	5,507	6,255	6,998	7,745
B.T.U./Gal. Liq @ 60° F.		68,900	91,300	99,300	103,000 56	108,700	110,000 56	114,900 56	118,500 56	121,300 56	123,500 56	125,300 56
Explosion Limits—Lower % in air	4.9-6-2 31	3.0-3.3 31	2.0-2.4 31	1.80 31	1.5-1.9 31	1.32 45	0.3-2.5 31	1.1-1.3 31	1.0-1.1 31	0.95 45	0.83 45	0.67 45
Upper % in air	12.7-16.0	10.6-15.0	7.0-9.5	8.44	5.7-8.5	——	4.5-7.5	4.2-6.0	3.6-6.0	——	——	——
Cu. Ft. Air to burn 1 cu. ft. gas	9.55	16.71	23.87	31.03	31.03	38.19	38.19	45.35	52.06	59.67	66.83	73.99
Heat of Vaporiz. 14.696 Lbs./sq. in. Abs B.T.U./Lb. at B.P	245 50	211 50	183 50	158 50	166 50	146 50	153 50	146 50	138 50	131 50	125 50	120 50
Specific Heat 14.696 Lbs./sq. in. Abs. C_p Vapor B.t.u./Lb °F.	0.526 4, 47, 49	0.413 4, 47, 49	0.390 4, 47, 49	0.406 4, 47, 49	0.396 4, 47, 49	0.413 4, 47, 49	0.402 4, 47, 49	0.406 4, 47, 49	0.415 4, 47, 49	0.420 4, 47, 49	0.429 4, 47, 49	0.436 4, 47, 49
C_v Vapor B.t.u./Lb. °F	0.402	0.347	0.346	0.373	0.363	0.387	0.376	0.384	0.397	0.404	0.415	0.424
$N = C_p/C_v$ B.t.u./Lb. °F	1.306	1.189	1.128	1.088	1.090	1.066	1.070	1.057	1.045	1.040	1.034	1.028
C_p Liquid B t.u./Lb °F.	—	—	—		0.55@32 24		0.55 53	0.536 6	0.522	0.519	0.518 48	0.517 48
Vapor Pressure @ 100° F., Lb./Sq. In. Abs.	—	—	189.5 46, 10	73.5 26, 24	52.0 22, 18	20.3 24	15.5 11, 18	5.0 24, 18	1.63 24, 18	0.54 42	0.19 42	0.06 42
Aniline Point °F.				225.7 46	181.2 46	174.0 46	159.3 51	155.5 46	159.1 46	161.1 46	166.1 46	171.5 46
Refractive Index N_D^{20C}						1.3540 51	1.3577 51	1.3750 51	1.3878 51	1.3976 51	1.4056 51	1.4120 43

1. Sub-numerals shown with values refer to references in the bibliography. Where none are given, the values were calculated from those with references

*Gross Heat on dry basis at 14.696 Lbs./sq. in. Abs. and 60° F To convert to water saturation basis, multiply by 0.9825

**Apparent values for dissolved Methane @ 60° F.

***Based on "perfect gas."

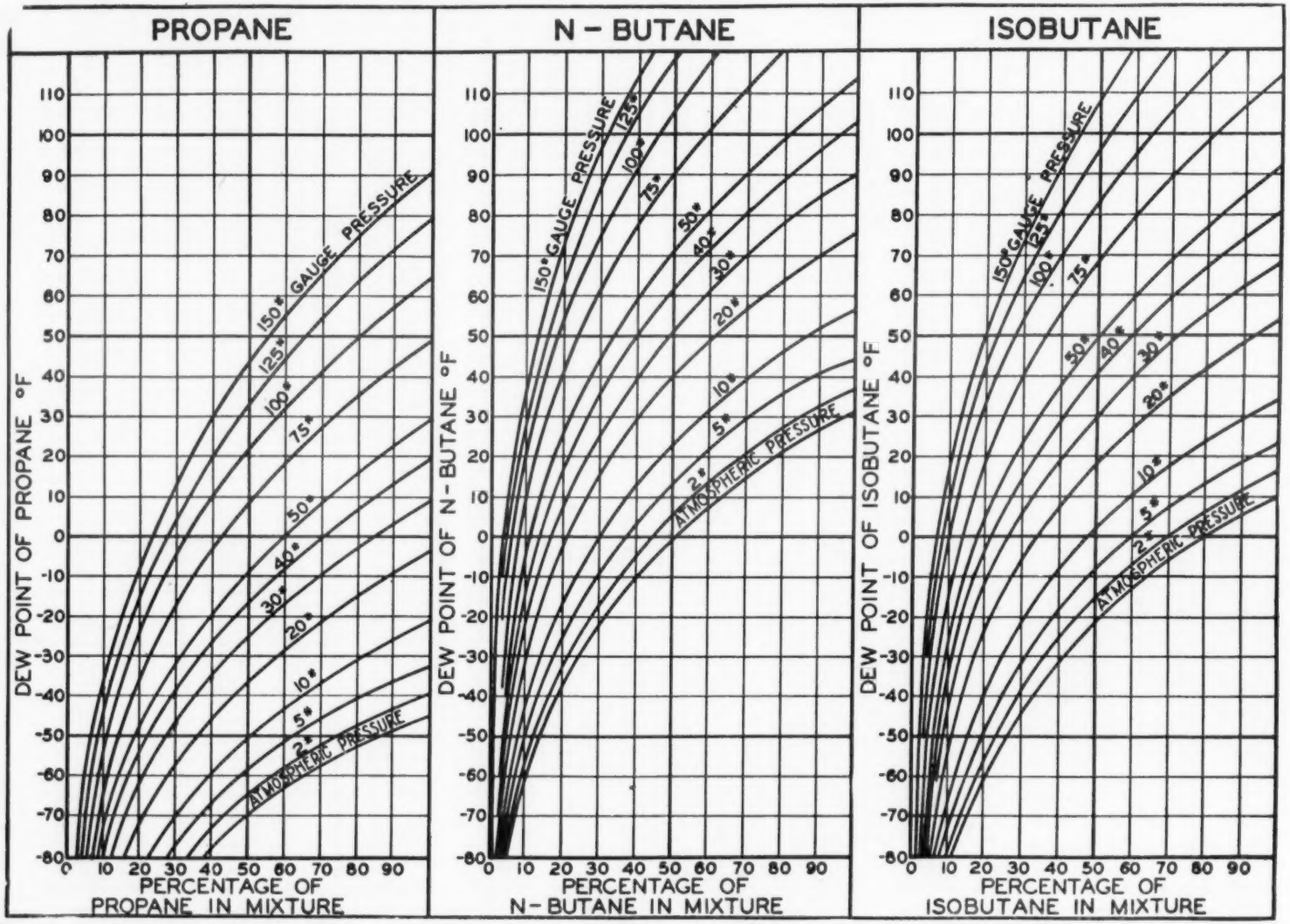
1. Sub-numerals shown with values refer to references in the bibliography. Where none are given, the values were calculated from those with references

by 0.0825

**Apparent values for dissolved Methane @ 60° F.

***Based on "perfect gas."

DEW POINTS OF PROPANE, NORMAL BUTANE AND ISOBUTANE, CARBURETTED WITH AIR



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N.G.A.A. SPECIFIC GRAVITY CONVERSION FACTORS (1942)

Observed Temperature Degrees Fahrenheit	OBSERVED SPECIFIC GRAVITY																																
	0.42	0.43	0.44	0.45	0.46	0.47	0.48	0.49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.70	0.71	0.72	0.73
	CORRESPONDING SPECIFIC GRAVITIES 60° F./60° F.																																
−50																0.487	0.500	0.513	0.526	0.538	0.550	0.562	0.575	0.587	0.599								
−45																0.491	0.504	0.517	0.529	0.542	0.554	0.566	0.578	0.590									
−40															0.483	0.495	0.508	0.521	0.533	0.545	0.558	0.570	0.581	0.593									
−35															0.487	0.500	0.512	0.525	0.537	0.549	0.561	0.573	0.585	0.596									
−30															0.491	0.504	0.516	0.529	0.541	0.552	0.564	0.576	0.588	0.600									
−25															0.496	0.508	0.520	0.532	0.544	0.556	0.568	0.580	0.591										
−20														0.488	0.500	0.512	0.524	0.536	0.548	0.559	0.571	0.583	0.594										
−15														0.492	0.504	0.516	0.528	0.540	0.552	0.563	0.574	0.586	0.597										
−10													0.484	0.496	0.508	0.520	0.532	0.543	0.555	0.566	0.578	0.589	0.601										
− 5													0.488	0.500	0.512	0.524	0.536	0.547	0.559	0.570	0.581	0.593											
0												0.481	0.493	0.505	0.516	0.528	0.540	0.551	0.562	0.573	0.585	0.596	0.607	0.618	0.628	0.639	0.649	0.659	0.670	0.680	0.690	0.700	
2												0.483	0.495	0.506	0.517	0.529	0.541	0.552	0.563	0.574	0.586	0.597	0.608	0.619	0.629	0.640	0.650	0.660	0.671	0.681	0.691	0.701	
4												0.484	0.496	0.508	0.519	0.531	0.542	0.553	0.564	0.576	0.587	0.598	0.609	0.620	0.630	0.641	0.651	0.661	0.672	0.682	0.692	0.702	
6												0.486	0.498	0.509	0.520	0.532	0.544	0.555	0.566	0.577	0.589	0.599	0.610	0.621	0.631	0.642	0.652	0.662	0.673	0.683	0.693	0.703	
8												0.487	0.499	0.511	0.522	0.534	0.545	0.556	0.567	0.579	0.590	0.600	0.611	0.622	0.632	0.643	0.653	0.663	0.674	0.684	0.694	0.704	
10												0.489	0.501	0.512	0.523	0.535	0.546	0.557	0.568	0.580	0.591	0.601	0.612	0.623	0.633	0.644	0.654	0.664	0.675	0.685	0.695	0.705	
12												0.491	0.503	0.514	0.525	0.536	0.547	0.558	0.569	0.581	0.592	0.602	0.613	0.624	0.634	0.645	0.655	0.665	0.676	0.686	0.696	0.706	
14												0.492	0.504	0.515	0.526	0.538	0.549	0.560	0.571	0.582	0.593	0.604	0.614	0.625	0.635	0.646	0.656	0.666	0.677	0.687	0.697	0.707	
16												0.494	0.506	0.517	0.528	0.539	0.550	0.561	0.572	0.584	0.595	0.605	0.616	0.626	0.637	0.647	0.657	0.667	0.678	0.688	0.698	0.708	
18												0.495	0.507	0.518	0.529	0.541	0.552	0.563	0.574	0.585	0.596	0.607	0.617	0.627	0.638	0.648	0.658	0.668	0.679	0.689	0.699	0.709	
20											0.486	0.497	0.509	0.520	0.531	0.542	0.553	0.564	0.575	0.586	0.597	0.608	0.618	0.628	0.639	0.649	0.659	0.669	0.680	0.690	0.700	0.710
22											0.488	0.499	0.511	0.522	0.533	0.544	0.554	0.565	0.576	0.587	0.598	0.609	0.619	0.629	0.640	0.650	0.660	0.670	0.681	0.691	0.701	
24											0.490	0.501	0.512	0.523	0.534	0.545	0.556	0.567	0.578	0.588	0.599	0.610	0.620	0.630	0.641	0.651	0.661	0.671	0.682	0.692	0.702	
26											0.491	0.502	0.514	0.525	0.536	0.547	0.557	0.568	0.579	0.590	0.600	0.611	0.621	0.632	0.642	0.652	0.662	0.673	0.683	0.693	0.703	
28											0.493	0.504	0.515	0.526	0.537	0.548	0.559	0.570	0.581	0.591	0.601	0.612	0.622	0.633	0.643	0.653	0.663	0.674	0.684	0.694	0.704	
30										0.484	0.495	0.506	0.517	0.528	0.539	0.550	0.560	0.571	0.582	0.592	0.602	0.613	0.623	0.634	0.644	0.654	0.664	0.675	0.685	0.695	0.705	
32										0.486	0.497	0.508	0.519	0.530	0.540	0.551	0.561	0.572	0.583	0.593	0.603	0.614	0.624	0.635	0.645	0.655	0.665	0.676	0.686	0.696	0.706	
34										0.488	0.499	0.509	0.520	0.531	0.542	0.553	0.563	0.574	0.584	0.595	0.605	0.615	0.626	0.636	0.646	0.656	0.666	0.677	0.687	0.697	0.707	
36										0.489	0.500	0.511	0.522	0.533	0.543	0.554	0.564	0.575	0.586	0.596	0.606	0.617	0.627	0.638	0.648	0.658	0.668	0.678	0.688	0.698	0.708	
38										0.491	0.502	0.512	0.523	0.534	0.545	0.556	0.566	0.577	0.587	0.598	0.608	0.618	0.629	0.639	0.649	0.659	0.669	0.679	0.689	0.699	0.709	
40									0.483	0.493	0.504	0.514	0.525	0.536	0.546	0.557	0.567	0.578	0.588	0.599	0.609	0.619	0.630	0.640	0.650	0.660	0.670	0.680	0.690	0.700	0.710	
42									0.485	0.495	0.506	0.516	0.527	0.537	0.547	0.558	0.568	0.579	0.589	0.600	0.610	0.620	0.631	0.641	0.651	0.661	0.671	0.681	0.691	0.701		
44									0.486	0.497	0.507	0.517	0.528	0.539	0.549	0.559	0.570	0.580	0.591	0.601	0.611	0.621	0.632	0.642	0.652	0.662	0.672	0.682	0.692	0.702		
46									0.488	0.498	0.509	0.519	0.530	0.540	0.550	0.561	0.571	0.582	0.592	0.603	0.613	0.623	0.633	0.643	0.653	0.663	0.673	0.683	0.693	0.703		
48									0.489	0.500	0.510	0.520	0.531	0.542	0.552	0.562	0.573	0.583	0.594	0.604	0.614	0.624	0.634	0.644	0.654	0.664	0.674	0.684	0.694	0.704		
50								0.480	0.491	0.502	0.512	0.522	0.533	0.543	0.553	0.563	0.574	0.584	0.595	0.605	0.615	0.625	0.635	0.645	0.655	0.665	0.675	0.685	0.695	0.705		
52								0.482	0.493	0.504	0.514	0.524	0.534	0.544	0.554	0.564	0.575	0.585	0.596	0.606	0.616	0.626	0.636	0.646	0.656	0.666	0.676	0.686	0.696	0.706		
54								0.484	0.494	0.505	0.515	0.525	0.536	0.546	0.556	0.566	0.576	0.586	0.597	0.607	0.617	0.627	0.637	0.647	0.657	0.667	0.677	0.687	0.697	0.707		
56								0.486	0.496	0.507	0.517	0.527	0.537	0.547	0.557	0.567	0.578	0.588	0.598	0.608	0.618	0.628	0.638	0.648	0.658	0.668	0.678	0.688	0.698	0.708		
58								0.488	0.498	0.508	0.518	0.529	0.539	0.549	0.559	0.569	0.579	0.589	0.599	0.609	0.619	0.629	0.639	0.649	0.659	0.669	0.679	0.689	0.699	0.709		
60							0.480	0.490	0.500	0.510	0.520	0.530	0.540	0.550	0.560	0.570	0.580	0.590	0.600	0.610	0.620	0.630	0.640	0.650	0.660	0.670	0.680	0.690	0.700	0.710		
62							0.482	0.492	0.502	0.512	0.522	0.532	0.541	0.551	0.561	0.571	0.581	0.591	0.601	0.611	0.621	0.631	0.641	0.651	0.661	0.671	0.681	0.691	0.701			
64							0.484	0.494	0.504	0.513	0.523	0.533	0.543	0.553	0.563	0.573	0.582	0.592	0.602	0.612	0.622	0.632	0.642	0.652	0.662	0.672	0.682	0.692	0.702			
66							0.485	0.495	0.505	0.515	0.525	0.535	0.544	0.554	0.564	0.574	0.584	0.594	0.604	0.614	0.624	0.634	0.644	0.654	0.663	0.673	0.683	0.693	0.703			
68							0.487	0.497	0.507	0.517	0.526	0.536	0.546	0.556	0.566	0.576	0.585	0.595	0.605	0.615	0.625	0.635	0.645	0.655	0.664	0.674	0.684	0.694	0.704			
70						0.479	0.489	0.499	0.509	0.518	0.528	0.538	0.547	0.557	0.567	0.577	0.586	0.596	0.606	0.616	0.626	0.636	0.646	0.656	0.665	0.675	0.685	0.695	0.705			
72						0.481	0.491	0.501	0.511	0.520	0.529	0.539	0.548	0.558	0.568	0.578	0.587	0.597	0.607	0.617	0.627	0.637	0.647	0.657	0.666	0.676	0.686	0.696	0.706			
74						0.483	0.493	0.502	0.512	0.521	0.531	0.541	0.550	0.560	0.569	0.579	0.589	0.598	0.608	0.618	0.628	0.638	0.648	0.658	0.667	0.677	0.687	0.697	0.707			
76						0.484	0.494	0.504	0.513	0.523	0.532	0.542	0.551	0.561	0.571	0.581	0.590	0.600	0.610	0.620	0.629	0.639	0.649	0.659	0.668	0.678	0.688	0.698	0.706			
78						0.486	0.496	0.505	0.515	0.524	0.534	0.544	0.553	0.563	0.572	0.582	0.592	0.601	0.611	0.621	0.630	0.640	0.650	0.660	0.669	0.679	0.689	0.699	0.709			
80					0.479	0.488	0.498	0.507	0.517	0.526	0.535	0.545	0.554	0.564	0.573	0.583	0.593	0.602	0.612	0.622	0.631	0.641	0.651	0.661	0.670	0.680	0.690	0.700	0.710			
82					0.481	0.490	0.500	0.509	0.519	0.528	0.537	0.546	0.555	0.565	0.574	0.584	0.594	0.603	0.613	0.623	0.632	0.642	0.652	0.662	0.671	0.681	0.691	0.701			
84					0.483	0.492	0.501	0.510	0.520	0.529	0.538	0.548	0.557	0.567	0.576	0.585	0.595	0.604	0.614	0.624	0.633	0.643	0.653	0.663	0.672	0.682	0.692	0.702			
86					0.484	0.493	0.503	0.512	0.521	0.531	0.540	0.549	0.558	0.568	0.577	0.587	0.597	0.606	0.616	0.625	0.635	0.644	0.654	0.664	0.673	0.683	0.693	0.703			
88					0.486	0.495	0.504	0.513	0.523	0.532	0.541	0.551	0.560	0.569	0.579	0.588	0.598	0.607	0.617	0.626	0.636	0.645	0.655	0.665	0.674	0.684	0.694	0.704			
90				0.479	0.488	0.497	0.506	0.515	0.524	0.534	0.543	0.552	0.561	0.570	0.580	0.589	0.599	0.608	0.618	0.627	0.637	0.646	0.656	0.666	0.675	0.685	0.695	0.705			
92				0.481	0.490	0.499	0.508	0.517	0.526	0.535	0.544	0.553	0.562	0.572	0.581	0.590	0.600	0.609	0.619	0.628	0.638	0.647	0.657	0.667	0.676	0.686	0.696	0.706			
94				0.483	0.492	0.500	0.509	0.518	0.528	0.537	0.545	0.554	0.563	0.573	0.582	0.591	0.601	0.610	0.620	0.629	0.639	0.648	0.658	0.668	0.677	0.687	0.697	0.707			
96				0.484	0.493	0.502	0.511	0.520	0.529	0.538	0.547	0.556	0.565	0.574	0.584	0.593	0.602	0.612	0.621	0.630	0.640	0.649	0.659	0.669	0.678	0.688	0.698	0.708			
98				0.486	0.495	0.503	0.512	0.521	0.531	0.540	0.548	0.557	0.566	0.575	0.585	0.594	0.603	0.613	0.622	0.631	0.641	0.650	0.660	0.670	0.679	0.689	0.699	0.709			
100			0.480	0.488	0.497	0.505	0.514	0.523	0.532	0.541	0.549	0.558	0.567	0.577	0.586	0.595	0.604	0.614	0.623	0.632	0.642	0.651	0.661	0.671	0.680	0.690	0.700	0.710			
105			0.485	0.493	0.502	0.510	0.518	0.527	0.535	0.544	0.553	0.562	0.571	0.580	0.589	0.598																
110		0.481	0.489	0.497	0.506	0.514	0.522	0.530	0.539	0.548	0.557	0.565	0.574	0.583	0.592																
115		0.485	0.493	0.501	0.510	0.518	0.526	0.534	0.543	0.551	0.560	0.568	0.577	0.586	0.595																
120	0.482	0.489	0.497	0.505	0.513	0.521	0.529	0.538	0.546	0.554	0.563	0.571	0.580	0.589	0.598																
125	0.486	0.494	0.502	0.509	0.517	0.525	0.533	0.541	0.550	0.558	0.566	0.574	0.583	0.592																	
130	0.491	0.498	0.506	0.514	0.521	0.529	0.537	0.545	0.553	0.561	0.569	0.577	0.586	0.595																	
135	0.495	0.502	0.510	0.517	0.525	0.533	0.541	0.549	0.557	0.565	0.573	0.581	0.589	0.598																	
140	0.499	0.506	0.514	0.521	0.529	0.536	0.544	0.552	0.560	0.568	0.576	0.584	0.592	0.601																	

Table 1. Illustration for Use. Given the specific gravity (t/60) 0.620 at 26° F. The specific gravity 60/60 will be found by moving down the column headed 0.620 to intersect with the horizontal lines from 26° F. The specific gravity 60/60 is found to be 0.600.

Natural Gasoline Association of America.

N.G.A.A. VOLUME CORRECTION FACTORS (1942)

N.G.A.A. VOLUME CORRECTION FACTORS (1942)

SPECIFIC GRAVITIES AT 60° F./60° F.

Observed Temperature Degrees Fahrenheit	0.500	Propane 0.5079	0.510	0.520	0.530	0.540	0.550	0.560	iso-Butane 0.5631	0.570	0.580	n-Butane 0.5844	0.590	0.600	0.610	0.620	iso-Pentane 0.6246	0.630	n-Pentane 0.6310	0.640	0.650	0.660	0.670	0.680	0.690	0.700
	VOLUME CORRECTION FACTORS																									
−50	1.160	1.155	1.153	1.146	1.140	1.133	1.127	1.122	1.120	1.116	1.111	1.108	1.106	1.102												
−45	1.153	1.148	1.146	1.140	1.134	1.128	1.122	1.117	1.115	1.111	1.106	1.103	1.101	1.097												
−40	1.147	1.142	1.140	1.134	1.128	1.122	1.117	1.111	1.110	1.106	1.101	1.099	1.097	1.093												
−35	1.140	1.135	1.134	1.128	1.122	1.116	1.112	1.106	1.105	1.101	1.096	1.094	1.092	1.088												
−30	1.134	1.129	1.128	1.122	1.116	1.111	1.106	1.101	1.100	1.096	1.092	1.090	1.088	1.084												
−25	1.127	1.122	1.121	1.115	1.110	1.105	1.100	1.095	1.094	1.091	1.087	1.085	1.083	1.080												
−20	1.120	1.115	1.114	1.105	1.104	1.099	1.095	1.090	1.089	1.086	1.082	1.080	1.079	1.076												
−15	1.112	1.109	1.107	1.102	1.097	1.093	1.089	1.084	1.083	1.080	1.077	1.075	1.074	1.071												
−10	1.105	1.102	1.100	1.095	1.091	1.087	1.083	1.079	1.078	1.075	1.072	1.071	1.069	1.066												
− 5	1.098	1.094	1.094	1.089	1.085	1.081	1.077	1.074	1.073	1.070	1.067	1.066	1.065	1.062												
0	1.092	1.088	1.088	1.084	1.080	1.076	1.073	1.069	1.068	1.066	1.063	1.062	1.061	1.058	1.055	1.053	1.052	1.051	1.051	1.050	1.048	1.046	1.045	1.044	1.043	1.042
2	1.089	1.086	1.085	1.081	1.077	1.074	1.070	1.067	1.066	1.064	1.061	1.060	1.059	1.056	1.053	1.051	1.050	1.049	1.049	1.048	1.046	1.045	1.044	1.043	1.042	1.041
4	1.086	1.083	1.082	1.079	1.075	1.071	1.068	1.065	1.064	1.062	1.059	1.058	1.057	1.054	1.051	1.049	1.049	1.048	1.048	1.047	1.045	1.043	1.042	1.041	1.041	1.039
6	1.084	1.080	1.080	1.076	1.072	1.069	1.065	1.062	1.061	1.059	1.057	1.055	1.054	1.052	1.050	1.048	1.047	1.046	1.046	1.045	1.043	1.042	1.041	1.040	1.039	1.038
8	1.081	1.078	1.077	1.074	1.070	1.066	1.063	1.060	1.059	1.057	1.055	1.053	1.052	1.050	1.048	1.046	1.045	1.045	1.045	1.044	1.042	1.040	1.039	1.038	1.037	1.036
10	1.078	1.075	1.074	1.071	1.067	1.064	1.061	1.058	1.057	1.055	1.053	1.051	1.050	1.048	1.046	1.044	1.044	1.043	1.043	1.042	1.040	1.039	1.038	1.037	1.036	1.035
12	1.075	1.072	1.071	1.068	1.064	1.061	1.059	1.056	1.055	1.053	1.051	1.049	1.048	1.046	1.044	1.042	1.042	1.041	1.041	1.040	1.038	1.037	1.036	1.035	1.035	1.034
14	1.072	1.070	1.069	1.066	1.062	1.059	1.056	1.053	1.053	1.051	1.049	1.047	1.046	1.044	1.042	1.041	1.040	1.039	1.039	1.038	1.037	1.036	1.035	1.034	1.033	1.032
16	1.070	1.067	1.066	1.063	1.060	1.056	1.054	1.051	1.050	1.048	1.046	1.045	1.044	1.043	1.041	1.039	1.039	1.038	1.038	1.036	1.036	1.034	1.033	1.032	1.032	1.031
18	1.067	1.065	1.064	1.061	1.057	1.054	1.051	1.049	1.048	1.046	1.044	1.043	1.042	1.041	1.039	1.038	1.037	1.036	1.036	1.035	1.034	1.033	1.032	1.031	1.030	1.029
20	1.064	1.062	1.061	1.058	1.054	1.051	1.049	1.046	1.046	1.044	1.042	1.041	1.040	1.039	1.037	1.036	1.035	1.034	1.034	1.033	1.032	1.031	1.030	1.029	1.029	1.028
22	1.061	1.059	1.058	1.055	1.052	1.049	1.046	1.044	1.044	1.042	1.040	1.039	1.038	1.036	1.035	1.034	1.033	1.032	1.032	1.031	1.030	1.030	1.029	1.028	1.028	1.027
24	1.058	1.056	1.055	1.052	1.049	1.046	1.044	1.042	1.042	1.040	1.038	1.037	1.036	1.034	1.033	1.032	1.032	1.031	1.031	1.030	1.029	1.028	1.027	1.026	1.026	1.025
26	1.055	1.053	1.052	1.049	1.047	1.044	1.042	1.039	1.039	1.037	1.036	1.036	1.034	1.033	1.032	1.031	1.030	1.029	1.029	1.028	1.027	1.027	1.026	1.025	1.024	1.024
28	1.052	1.050	1.049	1.047	1.044	1.041	1.039	1.037	1.037	1.035	1.034	1.034	1.032	1.031	1.030	1.029	1.028	1.028	1.028	1.027	1.026	1.025	1.024	1.023	1.023	1.022
30	1.049	1.047	1.046	1.044	1.041	1.039	1.037	1.035	1.035	1.033	1.032	1.032	1.030	1.029	1.028	1.027	1.027	1.026	1.026	1.025	1.024	1.024	1.023	1.022	1.022	1.021
32	1.046	1.044	1.043	1.041	1.038	1.036	1.035	1.033	1.033	1.031	1.030	1.030	1.028	1.027	1.026	1.025	1.025	1.024	1.024	1.023	1.022	1.022	1.021	1.021	1.020	1.020
34	1.043	1.041	1.040	1.038	1.036	1.034	1.032	1.031	1.030	1.029	1.028	1.028	1.026	1.025	1.024	1.023	1.023	1.022	1.022	1.022	1.021	1.021	1.020	1.019	1.019	1.018
36	1.039	1.038	1.037	1.035	1.033	1.031	1.030	1.028	1.028	1.027	1.025	1.025	1.024	1.023	1.023	1.022	1.021	1.021	1.021	1.020	1.019	1.019	1.018	1.018	1.017	1.017
38	1.036	1.035	1.034	1.032	1.031	1.029	1.027	1.026	1.025	1.025	1.023	1.023	1.022	1.021	1.021	1.020	1.020	1.019	1.019	1.019	1.018	1.018	1.017	1.016	1.016	1.015
40	1.033	1.032	1.031	1.029	1.028	1.026	1.025	1.024	1.023	1.023	1.021	1.021	1.020	1.019	1.019	1.018	1.018	1.017	1.017	1.017	1.016	1.016	1.015	1.015	1.014	1.014
42	1.030	1.029	1.028	1.027	1.025	1.024	1.023	1.022	1.021	1.021	1.019	1.019	1.018	1.018	1.017	1.016	1.016	1.015	1.015	1.015	1.014	1.014	1.013	1.013	1.013	1.013
44	1.027	1.026	1.025	1.023	1.022	1.021	1.020	1.019	1.019	1.018	1.017	1.017	1.016	1.016	1.015	1.014	1.014	1.014	1.014	1.013	1.013	1.013	1.012	1.012	1.011	1.011
46	1.023	1.022	1.022	1.021	1.020	1.018	1.018	1.017	1.016	1.016	1.015	1.015	1.014	1.014	1.013	1.013	1.013	1.012	1.012	1.012	1.011	1.011	1.010	1.010	1.010	1.010
48	1.020	1.019	1.019	1.018	1.017	1.016	1.015	1.014	1.014	1.013	1.013	1.013	1.012	1.012	1.011	1.011	1.011	1.011	1.011	1.010	1.010	1.010	1.009	1.009	1.008	1.008
50	1.017	1.016	1.016	1.015	1.014	1.013	1.013	1.012	1.012	1.011	1.011	1.011	1.010	1.010	1.009	1.009	1.009	1.009	1.009	1.008	1.008	1.008	1.007	1.007	1.007	1.007
52	1.014	1.013	1.012	1.012	1.011	1.010	1.010	1.009	1.009	1.009	1.009	1.009	1.008	1.008	1.007	1.007	1.007	1.007	1.007	1.007	1.006	1.006	1.006	1.006	1.006	1.005
54	1.010	1.010	1.009	1.009	1.008	1.008	1.007	1.007	1.007	1.007	1.006	1.006	1.006	1.006	1.006	1.005	1.005	1.005	1.005	1.005	1.005	1.005	1.004	1.004	1.004	1.004
56	1.007	1.007	1.006	1.006	1.005	1.005	1.005	1.005	1.005	1.005	1.004	1.004	1.004	1.004	1.004	1.004	1.004	1.003	1.003	1.003	1.003	1.003	1.003	1.003	1.003	1.003
58	1.003	1.003	1.003	1.003	1.003	1.003	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.001	1.001	1.001	1.001
60	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
62	0.997	0.997	0.997	0.997	0.997	0.997	0.997	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.999	0.999	0.999
64	0.993	0.993	0.994	0.994	0.994	0.994	0.995	0.995	0.995	0.995	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.997	0.997	0.997	0.997	0.997	0.997
66	0.990	0.990	0.990	0.990	0.991	0.992	0.992	0.993	0.993	0.993	0.993	0.993	0.993	0.994	0.994	0.994	0.995	0.995	0.995	0.995	0.995	0.995	0.995	0.996	0.996	0.996
68	0.986	0.986	0.987	0.987	0.988	0.989	0.990	0.990	0.990	0.990	0.991	0.991	0.991	0.992	0.992	0.993	0.993	0.993	0.993	0.994	0.994	0.994	0.994	0.994	0.994	0.994
70	0.983	0.983	0.984	0.984	0.985	0.986	0.987	0.988	0.988	0.988	0.989	0.989	0.989	0.990	0.990	0.991	0.991	0.991	0.991	0.992	0.992	0.992	0.992	0.993	0.993	0.993
72	0.979	0.980	0.981	0.981	0.982	0.983	0.984	0.985	0.986	0.986	0.987	0.987	0.987	0.988	0.988	0.989	0.989	0.989	0.989	0.990	0.990	0.990	0.991	0.991	0.992	0.992
74	0.976	0.976	0.977	0.978	0.980	0.980	0.982	0.983	0.983	0.984	0.985	0.985	0.985	0.986	0.986	0.987	0.987	0.987	0.987	0.988	0.988	0.989	0.989	0.990	0.990	0.990
76	0.972	0.973	0.974	0.975	0.977	0.978	0.979	0.980	0.981	0.981	0.982	0.982	0.983	0.984	0.985	0.986	0.986	0.986	0.986	0.987	0.987	0.987	0.988	0.988	0.989	0.989
78	0.969	0.970	0.970	0.972	0.974	0.975	0.977	0.978	0.978	0.979	0.980	0.980	0.981	0.982	0.983	0.984	0.984	0.984	0.984	0.985	0.986	0.986	0.986	0.987	0.987	0.987
80	0.965	0.967	0.967	0.969	0.971	0.972	0.974	0.975	0.976	0.977	0.978	0.978	0.979	0.980	0.981	0.982	0.982	0.982	0.982	0.983	0.984	0.984	0.985	0.985	0.986	0.986
82	0.961	0.963	0.963	0.966	0.968	0.969	0.971	0.972	0.973	0.974	0.976	0.976	0.977	0.978	0.979	0.980	0.980	0.980	0.980	0.981	0.982	0.983	0.983	0.984	0.984	0.985
84	0.957	0.959	0.960	0.962	0.965	0.966	0.968	0.970	0.971	0.972	0.974	0.974	0.975	0.976	0.977	0.978	0.979	0.979	0.979	0.980	0.981	0.981	0.982	0.982	0.983	0.983
86	0.954	0.956	0.956	0.959	0.961	0.964	0.966	0.967	0.968	0.969	0.971	0.971	0.972	0.973	0.975	0.976	0.977	0.977	0.977	0.978	0.979	0.980	0.980	0.981	0.981	0.982
88	0.950	0.952	0.953	0.955	0.958	0.961	0.963	0.965	0.966	0.967	0.969	0.969	0.970	0.971	0.973	0.974	0.975	0.976	0.976	0.977	0.978	0.978	0.979	0.979	0.980	0.980
90	0.946	0.949	0.949	0.952	0.955	0.958	0.960	0.962	0.963	0.964	0.967	0.967	0.968	0.969	0.971	0.972	0.973	0.974	0.974	0.975	0.976	0.977	0.977	0.978	0.978	0.979
92	0.942	0.945	0.946	0.949	0.952	0.955	0.957	0.959	0.960	0.962	0.964	0.965	0.966	0.967	0.969	0.970	0.971	0.972	0.972	0.973	0.974	0.975	0.975	0.976	0.977	0.977
94	0.938	0.941	0.942	0.946	0.949	0.952	0.954	0.957	0.958	0.959	0.962	0.962	0.964	0.965	0.967	0.968	0.969	0.970	0.970	0.971	0.972	0.973	0.974	0.975	0.975	0.976
96	0.935	0.938	0.939	0.942	0.946	0.949	0.952	0.954	0.955	0.957	0.959	0.960	0.961	0.963	0.965	0.966	0.967	0.968	0.968	0.970	0.971	0.972	0.972	0.973	0.974	0.975
98	0.931	0.934	0.935	0.939	0.943	0.946	0.949	0.952	0.953	0.954	0.957	0.957	0.959	0.961	0.963	0.964	0.965	0.966	0.966	0.968	0.969	0.970	0.971	0.972	0.972	0.973
100	0.927	0.930	0.932	0.936	0.940	0.943	0.946	0.949	0.950	0.952	0.954	0.955	0.957	0.959	0.961	0.962	0.963	0.964	0.964	0.966	0.967	0.968	0.969	0.970	0.971	0.972
105	0.917	0.920	0.923	0.927	0.931	0.935	0.939	0.943	0.943	0.946	0.949	0.949	0.951	0.954												
110	0.907	0.911	0.913	0.918	0.923	0.927	0.932	0.936	0.937	0.939	0.943	0.944	0.946	0.949												
115	0.897	0.902	0.904	0.909	0.915	0.920	0.925	0.930	0.930	0.933	0.937	0.938	0.940	0.944												
120	0.887	0.892	0.894	0.900	0.907	0.912	0.918	0.923	0.924	0.927	0.931	0.932	0.934	0.938												
125	0.876	0.881	0.884	0.890	0.898	0.903	0.909	0.916	0.916	0.920	0.925	0.927	0.928	0.933												
130	0.865	0.871	0.873	0.880	0.888	0.895	0.901	0.908	0.909	0.913	0.918	0.921	0.923	0.927												
135	0.854	0.861	0.863	0.871	0.879	0.887	0.894	0.901	0.902	0.907	0.912	0.914	0.916	0.921												
140	0.842	0.850	0.852	0.861	0.870	0.879	0.886	0.893	0.895	0.900	0.905	0.907	0.910	0.915												

Table 2. Illustration for Use. Given the specific (60/60) 0.600 and temperature of measurement of 26° F. The volume correction factor to convert the volume at the measured temperature of 26° F. to volume at 6° F. is found by moving down the column headed 0.600 to intersect with the horizontal line from 26° F. The volume correction factor is 1.033.

VAPOR PRESSURES OF PROPANE, BUTANE AND ISOBUTANE

Temp.	PROPANE		BUTANE		ISOBUTANE		Temp.
	PRESSURE—LBS. PER SQ. IN.						
Deg. F.	Absolute	Gauge	Absolute	Gauge	Absolute	Gauge	Deg. F.
—75	6.37	*17.0					—75
—70	7.37	*14.9					—70
—65	8.48	*12.7					—65
—60	9.72	*10.1					—60
—55	11.1	* 7.3					—55
—50	12.6	* 4.3					—50
—45	14.4	* 0.6					—45
—40	16.2	1.5					—40
—35	18.1	3.4					—35
—30	20.3	5.6					—30
—25	22.7	8.0					—25
—20	25.4	10.7			7.50	*14.6	—20
—15	28.3	13.6			8.30	*13.0	—15
—10	31.4	16.7			9.28	*11.0	—10
— 5	34.7	20.0			10.4	* 8.8	— 5
0	38.2	23.5	7.3	*15.0	11.6	* 6.3	0
5	41.9	27.2	8.2	*13.2	13.1	* 3.3	5
10	46.0	31.3	9.2	*11.1	14.6	* 0.2	10
15	50.6	35.9	10.4	* 8.8	16.3	1.6	15
20	55.5	40.8	11.6	* 6.3	18.2	3.5	20
25	60.9	46.2	13.0	* 3.6	20.2	5.5	25
30	66.3	51.6	14.4	* 0.6	22.3	7.6	30
35	72.0	57.3	16.0	1.3	24.6	9.9	35
40	78.0	63.3	17.7	3.0	26.9	12.2	40
45	84.6	69.9	19.6	4.9	29.5	14.8	45
50	91.8	77.1	21.6	6.9	32.5	17.8	50
55	99.3	84.6	23.8	9.1	35.5	20.8	55
60	107.1	92.4	26.3	11.6	38.7	24.0	60
65	115.4	100.7	28.9	14.2	42.2	27.5	65
70	124.0	109.3	31.6	16.9	45.8	31.1	70
75	133.2	118.5	34.5	19.8	49.7	35.0	75
80	142.8	128.1	37.6	22.9	53.9	39.2	80
85	153.1	138.4	40.9	26.2	58.6	43.9	85
90	164.0	149.0	44.5	29.8	63.3	48.6	90
95	175.0	160.0	48.2	33.5	68.4	53.7	95
100	187.0	172.0	52.2	37.5	73.7	59.0	100
105	200.0	185.0	56.4	41.7	79.3	64.6	105
110	212.0	197.0	60.8	46.1	85.1	70.4	110
115	226.0	211.0	65.6	50.9	91.4	76.7	115
120	240.0	225.0	70.8	56.1	98.0	83.3	120
125	254.0	239.0	76.0	61.3	104.8	90.1	125
130	272.0	257.3	81.4	66.7	112.0	97.3	130
135	288.0	273.3	87.0	72.3	119.3	104.6	135
140	305.0	290.3	92.6	77.9	126.8	112.1	140
145			100.0	85.3	136.0	121.3	145
150			108.0	93.7	145.0	130.3	150
155			115.0	100.3	155.0	140.3	155
160			122.0	107.3	165.0	150.3	160
165			130.0	115.3	175.0	160.3	165
170			140.0	125.3	186.0	171.3	170
175			150.0	135.3	198.0	183.3	175
180			160.0	145.3	210.0	195.3	180

*Inches of mercury below one standard atmosphere (29.92 in.).

Dana, Jenkins, Burdick and Timm, Refrigerating Engineering, June 1926.

VAPORIZATION OF LIQUID IN PROPANE TANKS

Many times the question arises, especially on peak shaving installations using propane: Is it necessary to turn on the vaporizers?

For comparatively short-time peak shaving it is possible to obtain sufficient vapor from the storage tank itself without passing liquid propane through the vaporizer.

It is a well-known fact that the vapor pressure of a gas bears a direct relationship to the temperature and that the latent heat of vaporization is the amount of heat required to convert a liquid to a gas (also known as boiling point) at given pressure and temperature conditions; and further:

"The rate of heat transfer has been set at 2 Btu per hour per degrees temperature differential per sq. ft. of tank area in contact with the liquid."

Knowing these basic gas laws, we can evolve a formula to determine the amount of liquid propane vaporized in a standard storage tank in one hour.

$$\frac{2 \text{ Btu} \times (T_1 - T_2) \times \text{wetted area in sq ft}}{\text{LH per gal.}} = \text{Gal/hr}$$

T_1 = Outside air temperature in degrees F

T_2 = Ultimate temperature in degrees F of propane liquid at minimum required pressure condition

LH per gal. = Latent Heat of vaporization (in Btu's) to vaporize one gallon of propane at T_2

As an example, let us assume that a 30,000 (wc) tank is half full of propane (wetted area = 1014 sq. ft.) and the outside air temperature is 80° F and the required vapor pressure can be as low as 10 psi gauge. How many gallons per hour is available due to the vaporization of liquid in storage tank?

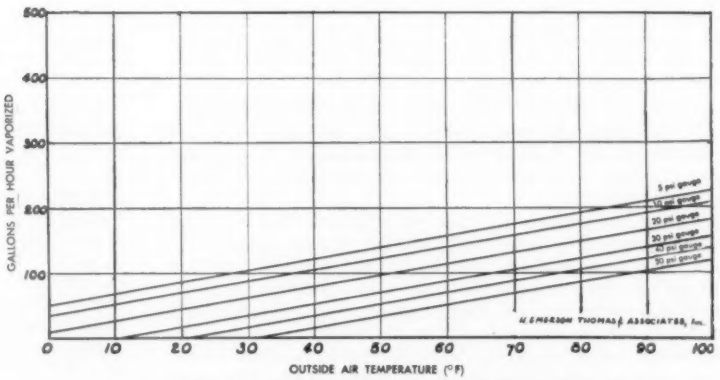
Referring to standard table of thermodynamic properties of propane; temperature at 10 psi ga is —20° F; and the latent heat of vaporization is 750 Btu per gal.

From the above formula—

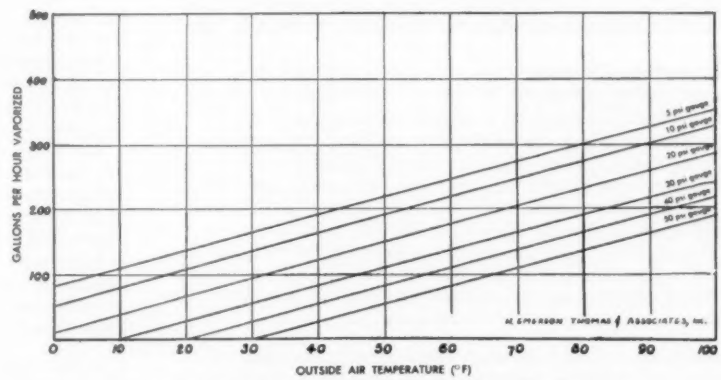
$$\frac{2 \text{ Btu} \times (80^\circ \text{F} - (-20^\circ \text{F})) \times 1014 \text{ sq ft}}{750 \text{ Btu per gal}} = 271 \text{ gal}$$

With the above conditions, we therefore can vaporize 271 gallons per hour without recourse to a vaporizer.

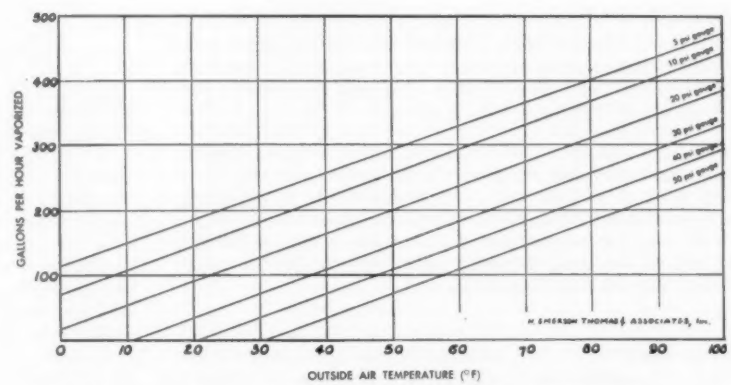
If this draw is maintained over a long period of time on a humid day, the surface of the tank in contact with the liquid will become frosted due to the refrigeration action of the liquid vaporized and the effective temperature differential will be substantially reduced.



Vaporization in 30,000 gallon tank, ¼ full—662 sq. ft.



Vaporization in 30,000 gallon tank, ½ full—1,014 sq. ft.



Vaporization in 30,000 gallon tank, ¾ full—1,365 sq. ft.

But in this discussion we are considering only comparatively short usages so as to obtain maximum vaporization.

Using the basic formula, graphs have been plotted which give available gallons per hour vaporized at various outside temperatures and pressure requirements of vapor and at varying filling heights in a 30,000 gallon (wc) tank containing commercial grade propane.

Referring to the graphs it is possible to decide when the vaporizer equipment will be required to obtain the necessary gas load.

Art E. Wastie, chief engineer, H. Emerson Thomas and Associates, Westfield, N. J.

STORAGE AND HANDLING OF LIQUEFIED PETROLEUM GASES

General. The term "liquefied petroleum gases" as used in these standards shall mean and include any material which is composed predominantly of any of the following hydrocarbons, or mixtures of them; propane, propylene, butanes (normal butane or isobutane), and butylenes.

Under moderate pressure the gases liquefy, but upon relief of the pressure are readily converted into the gaseous phase. Advantage of this characteristic is taken by the industry, and for convenience the gases are shipped and stored under pressure as liquids. When in the gaseous state, these gases present a hazard comparable to any flammable natural or manufactured gas, except that being heavier than air, ventilation requires added attention. The range of combustibility is considerably narrower than that of manufactured gas.

At atmospheric pressure and below 31° F. butane is a liquid. Propane is a liquid at atmospheric pressure at temperatures below minus 44° F. and normally does not present a flammable liquid hazard.

Rapid vaporization takes place at temperatures above the boiling points (butane about 30° F.; propane about minus 44° F.). Normal storage of these gases is as a liquid under pressure.

The following standards, here given in part, are intended to apply to the design, construction, location, installation, and operation of liquefied petroleum gas systems. These standards do not apply to marine terminals, pipe line and similar large volume terminals, natural gasoline plants, refineries, tank farms, or to chemical and utility gas manufacturing plants where specific approval of construction and installation plans is obtained from regulatory bodies having jurisdiction, provided such approval is based on substantially equivalent requirements.

Odorizing Gases. All liquefied petroleum gases shall be effectively odorized by an approved agent of such character as to indicate postively, by a distinctive odor, the presence of gas down to concentration in air of not over one-fifth the lower limit of combustibility.

NOTE: The lower limits of combustibility of the more commonly used liquefied petroleum gases are: Propane, 2.15 per cent; Butane, 1.55 per cent. These figures represent volumetric percentages of gas-air mixtures in each case.

Location of Containers and Regulating Equipment. Containers and first stage regulating equipment shall be located outside of buildings other than those especially provided for this purpose. Except as herein provided, each individual container shall be located with respect to nearest important building or group of buildings or line of adjoining property which may be built upon in accordance with the following table:

Water Capacity Per Container	Minimum Distance		Dist. Bet. Aboveground Containers
	Underground	Aboveground	
Less than 125 gallons	10 feet	None	None
125 to 500 gallons	10 feet	10 feet	3 feet
501 to 1,200 gallons	25 feet	25 feet	3 feet
Over 1,200 gallons	50 feet	50 feet	5 feet

In cases of bulk storage in heavily populated or congested areas, the inspection department having jurisdiction shall determine restrictions of individual container capacity, total storage, and distance to line of adjoining property which may be built on and other reasonable protective methods.

In industrial installations involving containers of 150,000 gallons aggregate capacity or more, where serious mutual exposures between the container and adjacent properties prevail, the enforcing authority having jurisdiction may require fire walls designed and constructed in accordance with good engineering practice.

In the case of buildings devoted exclusively to gas manufacturing and distributing operations the above distances may be reduced provided that in no case shall containers of capacity exceeding 500 gallons be located closer than 10 ft. to such gas manufacturing and distributing buildings.

Readily ignitable material such as weeds and long dry grass shall be removed within ten feet of any container.

Container Valves and Accessories, Filler Pipes and Discharge Pipes. All shut-off valves and accessory equipment (liquid or gas) shall be approved for use with liquefied petroleum gas, and designed for not less than the maximum pressure to which they may be subjected. Valves which may be subject to container pressure shall have a rated working pressure of at least 250 pounds per square inch gauge.

All connections to containers, except safety relief connections and gauging devices shall have shut-off valves located as close to the container as practicable.

The filling pipe inlet terminal shall not be located inside a building. Such terminals shall be located not less than 10 feet from any building and preferably not less than 5 feet from any driveway, and shall be located in a protective housing built for the purpose.

The filling connection shall be fitted with an approved combination back-pressure check valve and excess flow valve; a double or 2 back-pressure check valves; or a positive shut-off valve, in conjunction with either an internal back-pressure valve or an internal excess flow valve.

All liquid and vapor connections to containers except filling pipes and safety relief connections shall be equipped with approved automatic excess flow valves, except that no excess flow valve is required in the withdrawal serviee line, provided that:

1. The discharge from the service outlet is controlled by a suitable manually operated shut-off valve:
   (a) threaded directly into the service outlet of the container,
   (b) or which is an integral part of a substantial fitting threaded into or on the service outlet of the container,
   (c) or threaded directly into a substantial fitting threaded into or on the service outlet of the container.
2. The shut-off valve is equipped with an attached handwheel or the equivalent.
3. The controlling orifice between the contents of the container and the outlet of the shut-off valves does not exceed 5/16 in. in diameter for vapor withdrawal systems and ⅛ in. in diameter for liquid withdrawal systems.
4. An approved pressure-reducing regulator is directly attached to the outlet of the shut-off valve and is rigidly supported, or that an approved pressure-reducing regulator is attached to the outlet of the shut-off valve by means of a suitable flexible connection not longer than 20 in. and is rigidly supported.
5. Such systems' total water capacity does not exceed 1,200 U. S. gallons.

All inlet and outlet connections except safety relief valves, liquid level gauging devices and pressure gauges on containers of 1,200 gallons water capacity, or more, and on any container used to supply fuel directly to an internal combustion engine, shall be labeled to designate whether they communicate with vapor or liquid space. Labels may be on valves.

Excess flow valves where required by these standards shall close automatically at those rated flows of vapor or liquid as specified by the manufacturer. The connections or line including valves, fittings, etc., being protected by an excess flow valve shall have a greater capacity than the rated flow of the excess flow valve.

Liquid level gauging devices which are so constructed that outward flow of container contents shall not exceed that passed by a

No. 54 drill size opening, need not be equipped with excess flow valves.

Openings from tank or through fittings attached directly on tank to which pressure gauge connection is made need not be equipped with excess flow valve if such openings are protected by not larger than No. 54 drill size opening.

Excess flow and back pressure check valves where required by these standards shall be located inside of the container or at a point outside where the line enters the container; in the latter case, installation shall be made in such manner that any undue strain beyond the excess flow or back pressure check valve will not cause breakage between the container and such valve.

Excess flow valves may be designed with a by-pass, not to exceed a 60 drill size opening to allow equalization of pressures.

Piping, Tubing, and Fittings. Piping or tubing shall be wrought iron, steel, brass or copper pipe; or, except as hereinafter provided, seamless copper, brass, steel or other approved gas tubing. All piping or tubing shall be suitable for a working pressure of not less than 125 pounds per square inch. Copper tubing may be of the standard grade K or L. Aluminum tubing shall not be used in exterior locations or where it passes through masonry or plaster walls or insulation.

Pipe joints may be screwed, flanged, welded, brazed or soldered with a solder having a melting point of over 1000° F. Where fittings are used they shall have a working pressure of at least 125 pounds in systems where the operating pressure is 125 pounds per square inch or less. Extra heavy fittings shall be used for pressure exceeding 125 pounds per square inch or less. Cast iron fittings shall be prohibited. Joints on seamless copper, brass, steel, or non-ferrous gas tubing shall be made by means of approved gas tubing fittings or soldered with solders having a melting point exceeding 1000° F. Valve seat material, packing, gaskets, etc., shall be of such quality as to be resistant to the action of liquefied petroleum gas in the liquid phase.

Hose Specifications. Hose shall be fabricated of materials that are resistant to the action of liquefied petroleum gases.

Hose subject to container pressure shall be designed for a bursting pressure of not less than five times the pressure for which the container was designed. Hose connections when made shall be capable of withstanding a test pressure of twice the pressure for which the container is designed.

Filling Densities. The "filling density" is defined as the per cent ratio of the weight of the gas in a container to the weight of water the container will hold at 60° F. The filling densities for storage containers shall not exceed the ratios following:

MAXIMUM PERMITTED FILLING DENSITY

Specific Gravity at 60°	Aboveground Containers 0 to 1200 Gals.* Total Water Cap.	Aboveground Containers Over 1200 Gals. Total Water Cap.	Underground Containers All Capacities
.473—.480	38%	41%	42%
.481—.488	39	42	43
.489—.495	40	43	44
.496—.503	41	44	45
.504—.510	42	45	46
.511—.519	43	46	47
.520—.527	44	47	48
.528—.536	45	48	49
.537—.544	46	49	50
.545—.552	47	50	51
.553—.560	48	51	52
.561—.568	49	52	53
.569—.576	50	53	54
.577—.584	51	54	55
.585—.592	52	55	56
.593—.600	53	56	57
.601—.608	54	57	58
.609—.617	55	58	59
.618—.626	56	59	60
.627—.634	57	60	61

* Interstate Commerce Commission filling densities effective on the date of adoption of this standard.

Safety Devices. Every container and every vaporizer, whether heated by artificial means or not, shall be provided with one or more safety relief valves of spring-loaded or equivalent type. These valves shall be arranged to afford free vent to the outer air with discharge of not less than 5 ft. horizontally away from any opening into the building which is below such discharge. The area of the discharge shall be sufficient to prevent the building up of pressures in excess of 120% of the maximum permitted setting of the safety relief valves on the container and in accordance with the regulations of the National Board of Fire Underwriters, as contained in its Pamphlet No. 58. (Revised January, 1947.)

Container safety relief valves shall be set to start to discharge as follows, with relation to the container type:

Containers	Minimum	Maximum
A.S.M.E.-U-68, U-69	100%	125%
A.S.M.E.-U-200, U-201	90	100
A.P.I.-A.S.M.E.	80	100

Electrical Connections and Open Flames. In vaporizer or pump houses, in cylinder filling rooms and similar locations, all electrical installations shall be in strict accordance with the requirements of the National Electrical Code for Class I, Group D hazardous locations.

In vaporizer or pump houses, in cylinder filling rooms and similar locations, open flames or other sources of ignition shall not be permitted.

Design Working Pressure and Classification of Storage Containers. Storage containers shall be designed and classified as follows:

"Container Type"	For Gases with Vapor Pressure Not to Exceed Lbs. per Sq. In. Gauge at 100° F.	Minimum Design Working Pressure of Containers by: A.S.M.E. Code U-68 U-69	A.S.M.E. Code U-200 U-201	A.P.I.-A.S.M.E. Code
100	100	100 lb. Ga.	113 lb. Ga.	125 lb. Ga.
125	125	125 " "	141 " "	156 " "
150	150	150 " "	169 " "	187 " "
175	175	175 " "	197 " "	219 " "
200	200	200 " "	225 " "	250 " "

The shell or head thickness of any container shall not be less than 3/16 inch.

NOTE: Because of low soil temperature usually encountered, and the insulating effect of the earth, the average vapor pressure of products stored in underground containers will be materially lower than when stored aboveground. This reduction in actual operating pressure therefore provides a substantial corrosion allowance for these containers when installed underground.

Capacity of Liquid Containers. No liquid storage container shall exceed 30,000 standard U. S. gallons capacity.

Installation of Storage Containers. Containers installed aboveground (except "skid tanks") shall be provided with substantial masonry or non-combustible structural supports on firm masonry foundations.

Except as modified by the note, aboveground containers shall be supported as follows:

Horizontal containers shall be mounted on saddles and secured thereto in such a manner as to permit expansion and contraction. Every container shall be so supported as to prevent the concentration of excessive loads on the supporting portion of the shell. Structural metal supports may be employed when they are protected against fire in an approved manner. Suitable means of preventing corrosion shall be provided on that portion of the container in contact with the foundations or saddles.

NOTE: Containers of 1,200 gallons water capacity or less may be installed with non-fireproof ferrous metal supports if mounted on concrete pads or footings, and if the distance from the outside bottom of the container shell to the ground does not exceed 24 in.

(Information and data from publications of the National Board of Fire Underwriters: Pamphlet No. 58—Liquefied Petroleum Gases—March 1949. Pamphlet No. 59—Liquefied Petroleum Gases at Utility Gas Plants—March 1949.)

HEATING VALUE OF PETROLEUM OILS

CRUDE OILS, FUEL OILS AND KEROSENE

Gravity		Density	Total heat of combustion at constant volume, Q_v			Net heat of combustion at constant pressure, Q_p			Degrees A. P. I. at 60° F.
Degrees A. P. I. at 60° F.	Specific at 60°/60° F.	Pounds per gallon	Cal./g	Btu./lb.	Btu./gal.	Cal./g	Btu./lb.	Btu./gal.	
10	1. 0000	8. 337	10, 300	18, 540	154, 600	9, 740	17, 540	146, 200	**10**
11	. 9930	8. 279	10, 330	18, 590	153, 900	9, 770	17, 580	145, 600	11
12	. 9861	8. 221	10, 360	18, 640	153, 300	9, 790	17, 620	144, 900	12
13	. 9792	8. 164	10, 390	18, 690	152, 600	9, 810	17, 670	144, 200	13
14	. 9725	8. 108	10, 410	18, 740	152, 000	9, 840	17, 710	143, 600	14
15	. 9659	8. 053	10, 440	18, 790	151, 300	9, 860	17, 750	142, 900	**15**
16	. 9593	7. 998	10, 470	18, 840	150, 700	9, 880	17, 790	142, 300	16
17	. 9529	7. 944	10, 490	18, 890	150, 000	9, 900	17, 820	141, 600	17
18	. 9465	7. 891	10, 520	18, 930	149, 400	9, 920	17, 860	140, 900	18
19	. 9402	7. 839	10, 540	18, 980	148, 800	9, 940	17, 900	140, 300	19
20	. 9340	7. 787	10, 570	19, 020	148, 100	9, 960	17, 930	139, 600	**20**
21	. 9279	7. 736	10, 590	19, 060	147, 500	9, 980	17, 960	139, 000	21
22	. 9218	7. 686	10, 620	19, 110	146, 800	10, 000	18, 000	138, 300	22
23	. 9159	7. 636	10, 640	19, 150	146, 200	10, 020	18, 030	137, 700	23
24	. 9100	7. 587	10, 660	19, 190	145, 600	10, 040	18, 070	137, 100	24
25	. 9042	7. 538	10, 680	19, 230	145, 000	10, 050	18, 100	136, 400	**25**
26	. 8984	7. 490	10, 710	19, 270	144, 300	10, 070	18, 130	135, 800	26
27	. 8927	7. 443	10, 730	19, 310	143, 700	10, 090	18, 160	135, 200	27
28	. 8871	7. 396	10, 750	19, 350	143, 100	10, 110	18, 190	134, 600	28
29	. 8816	7. 350	10, 770	19, 380	142, 500	10, 120	18, 220	133, 900	29
30	. 8762	7. 305	10, 790	19, 420	141, 800	10, 140	18, 250	133, 300	**30**
31	. 8708	7. 260	10, 810	19, 450	141, 200	10, 150	18, 280	132, 700	31
32	. 8654	7. 215	10, 830	19, 490	140, 600	10, 170	18, 310	132, 100	32
33	. 8602	7. 171	10, 850	19, 520	140, 000	10, 180	18, 330	131, 500	33
34	. 8550	7. 128	10, 860	19, 560	139, 400	10, 200	18, 360	130, 900	34
35	. 8498	7. 085	10, 880	19, 590	138, 800	10, 210	18, 390	130, 300	**35**
36	. 8448	7. 043	10, 900	19, 620	138, 200	10, 230	18, 410	129, 700	36
37	. 8398	7. 001	10, 920	19, 650	137, 600	10, 240	18, 430	129, 100	37
38	. 8348	6. 960	10, 940	19, 680	137, 000	10, 260	18, 460	128, 500	38
39	. 8299	6. 920	10, 950	19, 720	136, 400	10, 270	18, 480	127, 900	39
40	. 8251	6. 879	10, 970	19, 750	135, 800	10, 280	18, 510	127, 300	**40**
41	. 8203	6. 839	10, 990	19, 780	135, 200	10, 300	18, 530	126, 700	41
42	. 8155	6. 799	11, 000	19, 810	134, 700	10, 310	18, 560	126, 200	42
43	. 8109	6. 760	11, 020	19, 830	134, 100	10, 320	18, 580	125, 600	43
44	. 8063	6. 722	11, 030	19, 860	133, 500	10, 330	18, 600	125, 000	44
45	. 8017	6. 684	11, 050	19, 890	132, 900	10, 340	18, 620	124, 400	**45**
46	. 7972	6. 646	11, 070	19, 920	132, 400	10, 360	18, 640	123, 900	46
47	. 7927	6. 609	11, 080	19, 940	131, 900	10, 370	18, 660	123, 300	47
48	. 7883	6. 572	11, 100	19, 970	131, 200	10, 380	18, 680	122, 800	48
49	7839	6. 536	11, 110	20, 000	130, 700	10, 390	18, 700	122, 200	49

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Table 1.

VOLATILE PETROLEUM PRODUCTS

Gravity		Density	Total heat of combustion at constant volume, Q_v			Net heat of combustion at constant pressure, Q_p			Degrees A. P. I. at 60° F.
Degrees A. P. I. at 60° F.	Specific at 60°/60° F.	Pounds per gallon	Cal./g	Btu./lb.	Btu./gal.	Cal./g	Btu./lb.	Btu./gal.	
50	0. 7796	6. 500	11, 120	20, 020	130, 100	10, 400	18, 720	121, 700	**50**
51	. 7753	6. 464	11, 140	20, 050	129, 600	10, 410	18, 740	121, 100	51
52	. 7711	6. 429	11, 150	20, 070	129, 000	10, 420	18, 760	120, 600	52
53	. 7669	6. 394	11, 160	20, 100	128, 500	10, 430	18, 780	120, 100	53
54	. 7628	6. 360	11, 180	20, 120	128, 000	10, 440	18, 800	119, 500	54
55	. 7587	6. 326	11, 190	20, 140	127, 400	10, 450	18, 810	119, 000	**55**
56	. 7547	6. 292	11, 200	20, 170	126, 900	10, 460	18, 830	118, 500	56
57	. 7507	6. 258	11, 220	20, 190	126, 400	10, 470	18, 850	118, 000	57
58	. 7467	6. 225	11, 230	20, 210	125, 800	10, 480	18, 870	117, 500	58
59	. 7428	6. 193	11, 240	20, 230	125, 300	10, 490	18, 880	116, 900	59
60	. 7389	6. 160	11, 250	20, 260	124, 800	10, 500	18, 900	116, 400	**60**
61	. 7351	6. 128	11, 270	20, 280	124, 300	10, 510	18, 920	115, 900	61
62	. 7313	6. 097	11, 280	20, 300	123, 700	10, 520	18, 930	115, 400	62
63	. 7275	6. 065	11, 290	20, 320	123, 200	10, 530	18, 950	114, 900	63
64	. 7238	6. 034	11, 300	20, 340	122, 700	10, 540	18, 960	114, 400	64
65	. 7201	6. 004	11, 310	20, 360	122, 200	10, 540	18, 980	113, 900	**65**
66	. 7165	5. 973	11, 320	20, 380	121, 700	10, 550	18, 990	113, 400	66
67	. 7128	5. 943	11, 330	20, 400	121, 200	10, 560	19, 010	112, 900	67
68	. 7093	5. 913	11, 340	20, 420	120, 700	10, 570	19, 020	112, 500	68
69	. 7057	5. 884.	11, 350	20, 440	120, 200	10, 580	19, 040	112, 000	69
70	. 7022	5. 855	11, 360	20, 460	119, 800	10, 580	19, 050	111, 500	**70**
72	. 6953	5. 797	11, 380	20, 490	118, 800	10, 600	19, 080	110, 600	72
74	. 6886	5. 741	11, 400	20, 530	117, 900	10, 610	19, 100	109, 700	74
76	. 6819	5. 685	11, 420	20, 560	116, 900	10, 630	19, 130	108, 800	76
78	. 6754	5. 631	11, 440	20, 600	116, 000	10, 640	19, 150	107, 900	78
80	. 6690	5. 578	11, 460	20, 630	115, 100	10, 650	19, 180	107, 000	**80**
82	. 6628	5. 526	11, 480	20, 660	114, 200	10, 670	19, 200	106, 100	82
84	. 6566	5. 474	11, 490	20, 690	113, 300	10, 680	19, 220	105, 200	84
86	. 6506	5. 424	11, 510	20, 720	112, 400	10, 690	19, 240	104, 400	86
88	. 6446	5. 375	11, 530	20, 750	111, 500	10, 700	19, 260	103, 500	88
90	. 6388	5. 326	11, 540	20, 780	110, 700	10, 710	19, 280	102, 700	**90**
92	. 6331	5. 278	11, 560	20, 810	109, 800	10, 720	19, 300	101, 900	92
94	. 6275	5. 232	11, 570	20, 830	109, 000	10, 740	19, 320	101, 100	94
96	. 6220	5. 186	11, 590	20, 860	108, 100	10, 750	19, 340	100, 300	96
98	. 6166	5. 140	11, 600	20, 880	107, 300	10, 760	19, 360	99, 500	98
100	. 6112	5. 096	11, 620	20, 910	106, 500	10, 770	19, 380	98, 700	**100**
105	. 5983	4. 988	11, 650	20, 970	104, 600	10, 790	19, 420	96, 800	105
110	. 5859	4. 885	11, 680	21, 020	102, 700	10, 810	19, 460	95, 100	110
115	. 5740	4. 786	11, 710	21, 070	100, 900	10, 830	19, 490	93, 300	115
120	. 5626	4. 691	11, 740	21, 120	99, 100	10, 850	19, 530	91, 600	120
125	. 5517	4. 599	11, 760	21, 170	97, 400	10, 860	19, 560	90, 000	**125**
130	. 5411	4. 511	11, 790	21, 210	95, 700	10, 880	19, 590	88, 400	130
135	. 5310	4. 427	11, 810	21, 250	94, 100	10, 900	19, 610	86, 800	135
140	. 5212	4. 345	11, 830	21, 290	92, 500	10, 910	19, 640	85, 300	140
145	. 5118	4. 267	11, 850	21, 330	91, 000	10, 920	19, 660	83, 900	145

Table 2.

HEATING VALUE OF PETROLEUM OILS

In most practical applications of the combustion of petroleum products, the process is carried out at constant pressure (atmospheric) and the water vapor formed in combustion is not condensed. For such processes, therefore, the net heat of combustion at constant pressure is the more significant quantity in making comparisons of fuels and in calculating the efficiencies of heating appliances.

Heats of Combustion of Crude Oils, Fuel Oils, and Kerosenes

The data on heats of combustion (heating values) given in Table I apply to petroleum oils free from water, ash, and sulphur with an estimated accuracy of 1 per cent. These data are based on experimental results obtained, on a total of 630 petroleum oils from 8 States and 10 foreign countries, by 5 groups of observers.

Heats of Combustion of Volatile Petroleum Products

The data on heats of combustion (heating values) given in Table II apply to volatile petroleum liquids in general with an estimated accuracy of 1 per cent. The values given are probably too high by 1 or 2 per cent for products containing unusually large amounts of aromatic hydrocarbons; for example, "vapor phase cracked" gasoline. The tabulated values should be increased by about 1 per cent to yield corresponding value for the heats of combustion of the vapor (vaporized product); that is, for those instances in which the latent heat of vaporization is supplied by the external surroundings and not by the combustion of the product.

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OIL TEMPERATURE CORRECTION FACTORS

Oil Temperature Correction Factors—to 60° F.

Observed Temperature ° F.	Degrees A. P. I. 5.0° to 9.9°	10.0° to 14.9°	15.0° to 19.9°	20.0° to 24.9°	25.0° to 29.9°	30.0° to 34.9°	35.0° to 39.9°	40.0° to 49.9°	50.0° to 59.9°
0	1.0215	1.0227	1.0235	1.0243	1.0251	1.0262	1.0276	1.0301	1.0347
2	1.0208	1.0219	1.0227	1.0235	1.0243	1.0253	1.0267	1.0291	1.0335
4	1.0201	1.0211	1.0219	1.0226	1.0234	1.0244	1.0258	1.0281	1.0324
6	1.0193	1.0203	1.0211	1.0218	1.0226	1.0236	1.0248	1.0271	1.0312
8	1.0186	1.0196	1.0203	1.0210	1.0217	1.0227	1.0239	1.0261	1.0301
10	1.0179	1.0188	1.0195	1.0202	1.0209	1.0218	1.0230	1.0251	1.0290
12	1.0171	1.0180	1.0187	1.0194	1.0201	1.0209	1.0221	1.0241	1.0278
14	1.0164	1.0173	1.0179	1.0185	1.0192	1.0200	1.0212	1.0231	1.0267
16	1.0157	1.0165	1.0171	1.0177	1.0184	1.0192	1.0203	1.0221	1.0255
18	1.0150	1.0158	1.0164	1.0169	1.0175	1.0183	1.0194	1.0211	1.0244
20	1.0144	1.0150	1.0156	1.0161	1.0167	1.0174	1.0184	1.0201	1.0232
22	1.0137	1.0142	1.0148	1.0153	1.0159	1.0165	1.0175	1.0191	1.0220
24	1.0129	1.0135	1.0140	1.0144	1.0150	1.0156	1.0166	1.0181	1.0209
26	1.0122	1.0127	1.0132	1.0136	1.0142	1.0148	1.0156	1.0171	1.0197
28	1.0115	1.0120	1.0125	1.0128	1.0133	1.0139	1.0147	1.0161	1.0186
30	1.0108	1.0112	1.0117	1.0120	1.0125	1.0130	1.0138	1.0151	1.0174
32	1.0100	1.0105	1.0109	1.0112	1.0117	1.0121	1.0129	1.0141	1.0162
34	1.0093	1.0097	1.0101	1.0104	1.0108	1.0112	1.0120	1.0131	1.0151
36	1.0085	1.0089	1.0093	1.0096	1.0100	1.0104	1.0110	1.0121	1.0139
38	1.0078	1.0082	1.0085	1.0088	1.0091	1.0095	1.0101	1.0110	1.0128
40	1.0071	1.0074	1.0077	1.0080	1.0083	1.0087	1.0092	1.0100	1.0116
42	1.0064	1.0067	1.0069	1.0072	1.0075	1.0078	1.0082	1.0090	1.0104
44	1.0057	1.0060	1.0062	1.0064	1.0066	1.0069	1.0073	1.0080	1.0093
46	1.0049	1.0052	1.0054	1.0056	1.0058	1.0061	1.0064	1.0070	1.0081
48	1.0042	1.0045	1.0046	1.0048	1.0050	1.0052	1.0055	1.0060	1.0070
50	1.0035	1.0037	1.0038	1.0040	1.0042	1.0043	1.0046	1.0050	1.0058
52	1.0028	1.0029	1.0030	1.0032	1.0034	1.0035	1.0037	1.0041	1.0046
54	1.0021	1.0022	1.0023	1.0024	1.0025	1.0026	1.0028	1.0030	1.0035
56	1.0014	1.0014	1.0015	1.0016	1.0017	1.0018	1.0018	1.0020	1.0023
58	1.0007	1.0007	1.0008	1.0008	1.0008	1.0009	1.0009	1.0010	1.0012
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
62	.9993	.9993	.9992	.9992	.9992	.9991	.9991	.9990	.9988
64	.9986	.9986	.9985	.9984	.9983	.9982	.9982	.9980	.9977
66	.9979	.9978	.9977	.9976	.9975	.9974	.9972	.9970	.9965
68	.9972	.9971	.9970	.9968	.9966	.9965	.9963	.9960	.9954
70	.9965	.9963	.9962	.9960	.9958	.9957	.9954	.9950	.9942
72	.9958	.9956	.9954	.9952	.9950	.9949	.9945	.9940	.9930
74	.9951	.9949	.9946	.9944	.9942	.9940	.9936	.9929	.9919
76	.9943	.9941	.9938	.9936	.9934	.9932	.9927	.9919	.9907
78	.9937	.9934	.9931	.9929	.9926	.9923	.9918	.9909	.9896
80	.9930	.9927	.9924	.9921	.9918	.9914	.9909	.9899	.9884
82	.9923	.9919	.9916	.9913	.9910	.9905	.9899	.9889	.9871
84	.9916	.9912	.9908	.9905	.9901	.9896	.9890	.9879	.9860
86	.9909	.9904	.9900	.9897	.9893	.9888	.9880	.9869	.9848
88	.9902	.9897	.9893	.9889	.9884	.9879	.9871	.9859	.9837
90	.9895	.9890	.9885	.9881	.9876	.9870	.9862	.9849	.9825
92	.9888	.9883	.9877	.9873	.9868	.9861	.9853	.9839	.9813
94	.9881	.9875	.9870	.9865	.9860	.9852	.9844	.9829	.9802
96	.9874	.9867	.9862	.9857	.9852	.9844	.9834	.9819	.9790
98	.9867	.9860	.9855	.9849	.9843	.9835	.9825	.9809	.9779
100	.9860	.9853	.9847	.9841	.9835	.9827	.9816	.9799	.9767
102	.9853	.9846	.9839	.9833	.9827	.9818	.9807	.9789	.9755
104	.9846	.9839	.9832	.9826	.9818	.9809	.9798	.9778	.9743
106	.9838	.9831	.9824	.9818	.9810	.9801	.9789	.9768	.9731
108	.9832	.9824	.9817	.9810	.9802	.9792	.9780	.9758	.9720
110	.9825	.9817	.9810	.9802	.9794	.9783	.9771	.9748	.9708
112	.9818	.9809	.9802	.9794	.9786	.9775	.9762	.9738	.9696
114	.9811	.9802	.9794	.9786	.9777	.9766	.9753	.9728	.9685
116	.9804	.9795	.9786	.9778	.9769	.9758	.9743	.9718	.9673
118	.9797	.9788	.9781	.9770	.9760	.9749	.9734	.9708	.9662
120	.9790	.9781	.9772	.9762	.9752	.9741	.9725	.9698	.9650

Compiled from Bureau of Standards Circular C410 (1936)

Multiply the volume of oil in the tank or car at the observed temperature by these factors to get the volume at 60 deg. F.

COMMERCIAL FUEL OIL STANDARDS

EFFECTIVE JANUARY 5, 1940

NATIONAL BUREAU OF STANDARDS CS12-40

TABLE 1.—*Detailed requirements for fuel oils* [a]

Grade [b]		Flash point (° F)		Pour point (° F)	Water and sediment (percent)	Carbon residue (percent)	Ash (percent)	Distillation temperatures (° F)				Viscosity seconds			
								10-percent point	90-percent point		End point	Saybolt universal (at 100° F)		Saybolt furol (at 122° F)	
Number	Description of fuel oil	Min	Max	Max	Max	Max	Max	Max	Max	Min	Max	Max	Min	Max	Min
1	Distillate oil for use in burners requiring a volatile fuel.	100 or legal	165	0	Trace	0.05 on 10% residuum [d]		410			[g] 550				
2	Distillate oil for use in burners requiring a moderately volatile fuel.	110 or legal	190	[g] 10	0.05	.25 on 10% residuum [f]		440	600						
3	Distillate oil for use in burners requiring a low-viscosity fuel.	110 or legal	230	[g] 20	.10	.15 straight			675	[g] 600		45			
5	Oil for use in burners requiring a medium viscosity fuel.	130 or legal			1.00		0.10						50	40	
6	Oil for use in burners equipped with preheaters, permitting a high viscosity fuel.	150			[h] 2.00									300	45

[a] Recognizing the necessity for low-sulfur fuel oils used in connection with heat treatment, nonferrous metal, glass and ceramic furnaces, and other special uses, a sulfur requirement may be specified in accordance with the following table:

Grade of fuel oil *Number*	Sulfur (maximum) *Percent*
1	0.5
2	.5
3	.75
5	No limit
6	No limit

Other sulfur limits may be specified only by mutual agreement between the buyer and seller.

[b] It is the intent of these classifications that failure to meet any requirement of a given grade does not automatically place an oil in the next lower grade unless in fact it meets all requirements of the lower grade.

[c] Lower or higher pour points may be specified whenever required by conditions of storage or use. However, these specifications shall not require a pour point lower than 0° F under any conditions.

[d] For use in other than sleeve-type blue-flame burners, carbon residue on 10-percent residuum may be increased to a maximum of 0.12 percent. This limit may be specified by mutual agreement between the buyer and seller.

[e] The maximum end point may be increased to 690° F when used in burners other than sleeve-type blue-flame burners.

[f] To meet certain burner requirements, the carbon-residue limit may be reduced to 0.15 percent on 10-percent residuum.

[g] The minimum distillation temperature of 600° F for 90 percent may be waived if API gravity is 26 or lower.

[h] Water by distillation, plus sediment by extraction. Sum, maximum 2.0 percent. The maximum sediment by extraction shall not exceed 0.50 percent. A deduction in quantity shall be made for all water and sediment in excess of 1.0 percent.

Commercial Standard CS12-40

COMPARISON OF DEGREES BAUME AND A P I WITH SPECIFIC GRAVITY

The general relationship between degrees Baumé and specific gravity is found in the following:

For liquids heavier than water—

$$\text{Sp. Gr.} = \frac{145}{145 - {}^\circ \text{ Baumé}} \text{ at } 60^\circ \text{ F.}$$

For liquids lighter than water—

$$\text{Sp. Gr.} = \frac{140}{130 + {}^\circ \text{ Baumé}} \text{ at } 60^\circ \text{ F.}$$

The corresponding relationship for degrees API is as follows.

$$\text{Sp. Gr.} = \frac{141.5}{131.5 + {}^\circ \text{ API}}$$

Deg.	Specific Gravity: Baumé: Liquids Heavier than Water	Specific Gravity: Baumé: Liquids Lighter than Water	Specific Gravity: API
0	1.000		
1.0	1.007		
2.0	1.014		
3.0	1.021		
4.0	1.028		
5.0	1.036		
6.0	1.043		
7.0	1.051		
8.0	1.058		
9.0	1.066		
10.0	1.074	1.000	1.000
11.0	1.082	.993	.993
12.0	1.090	.986	.986
13.0	1.098	.979	.979
14.0	1.107	.972	.973
15.0	1.115	.965	.966
16.0	1.124	.959	.959
17.0	1.133	.952	.953
18.0	1.142	.946	.947
19.0	1.151	.940	.940
20.0	1.160	.933	.934
21.0	1.169	.927	.928
22.0	1.179	.921	.922
23.0	1.188	.915	.916
24.0	1.198	.909	.910
25.0	1.208	.903	.904
26.0	1.218	.897	.898
27.0	1.229	.892	.893
28.0	1.239	.886	.887
29.0	1.250	.880	.882
30.0	1.261	.875	.876
31.0	1.272	.870	.871
32.0	1.283	.864	.865
33.0	1.295	.859	.860
34.0	1.306	.854	.855
35.0	1.318	.848	.850
36.0	1.330	.843	.845
37.0	1.343	.838	.840
38.0	1.355	.833	.835
39.0	1.368	.828	.830
40.0	1.381	.823	.825
41.0	1.394	.819	.820
42.0	1.408	.814	.816
43.0	1.422	.809	.811
44.0	1.436	.805	.806
45.0	1.450	.800	.802
46.0	1.465	.795	.797
47.0	1.480	.791	.793
48.0	1.495	.786	.788
49.0	1.510	.782	.784
50.0	1.526	.778	.780
51.0	1.543	.773	.775
52.0	1.559	.769	.771
53.0	1.576	.765	.767
54.0	1.593	.761	.763
55.0	1.611	.757	.759
56.0	1.629	.753	.755
57.0	1.648	.749	.751
58.0	1.667	.745	.747
59.0	1.686	.741	.743
60.0	1.706	.737	.739
61.0	1.726	.733	.735
62.0	1.747	.729	.731
63.0	1.768	.725	.728
64.0	1.790	.722	.724
65.0	1.812	.718	.720
66.0	1.835	.714	.717
67.0	1.859	.711	.713
68.0	1.883	.707	.709
69.0	1.908	.703	.706
70.0	1.933	.700	.702
71.0	1.959	.696	.699
72.0	1.986	.693	.695
73.0		.690	.692
74.0		.686	.689
75.0		.683	.685
76.0		.680	.682
77.0		.676	.679
78.0		.673	.675
79.0		.670	.672
80.0		.667	.669

VISCOSITY CONVERSION TABLE

The following table will give a comparison of various viscosity ratings so that if the viscosity is given in terms other than Saybolt Universal, it can be translated quickly by following horizontally to the Saybolt Universal column.

Kinematic Viscosity Centipoises = K	Seconds Saybolt Universal	Seconds Saybolt Furol	Seconds Redwood	Seconds Redwood Admiralty	Degrees Engler	Degrees Barbey
1.00	31	.....	29	.....	1.00	6200
2.56	35	.....	32.1	.....	1.16	2420
4.30	40	.....	36.2	5.10	1.31	1440
5.90	45	.....	40.3	5.52	1.46	1050
7.40	50	.....	44.3	5.83	1.58	838
8.83	55	.....	48.5	6.35	1.73	702
10.20	60	.....	52.3	6.77	1.88	618
11.53	65	.....	56.7	7.17	2.03	538
12.83	70	12.95	60.9	7.60	2.17	483
14.10	75	13.33	65.0	8.00	2.31	440
15.35	80	13.70	69.2	8.44	2.45	404
16.58	85	14.10	73.3	8.86	2.59	374
17.80	90	14.44	77.6	9.30	2.73	348
19.00	95	14.85	81.5	9.70	2.88	326
20.20	100	15.24	85.6	10.12	3.02	307
31.80	150	19.3	128	14.48	4.48	195
43.10	200	23.5	170	18.90	5.92	144
54.30	250	28.0	212	23.45	7.35	114
65.40	300	32.5	254	28.0	8.79	95
76.50	350	35.1	296	32.5	10.25	81
87.60	400	41.9	338	37.1	11.70	70.8
98.60	450	46.8	381	41.7	13.15	62.9
110.	500	51.6	423	46.2	14.60	56.4
121.	550	56.6	465	50.8	16.05	51.3
132.	600	61.4	508	55.4	17.50	47.0
143	650	66.2	550	60.1	19.00	43.4
154	700	71.1	592	64.6	20.45	40.3
165	750	76.0	635	69.2	21.90	37.6
176	800	81.0	677	73.8	23.35	35.2
187	850	86.0	719	78.4	24.80	33.2
198	900	91.0	762	83.0	26.30	31.3
209	950	95.8	804	87.6	27.70	29.7
220	1000	100.7	846	92.2	29.20	28.2
330	1500	150	1270	138.2	43.80	18.7
440	2000	200	1690	184.2	58.40	14.1
550	2500	250	2120	230	73.00	11.3
660	3000	300	2540	276	87.60	9.4
770	3500	350	2960	322	100.20	8.05
880	4000	400	3380	368	117.00	7.05
990	4500	450	3810	414	131.50	6.26
1100	5000	500	4230	461	146.00	5.64
1210	5500	550	4650	507	160.50	5.13
1320	6000	600	5080	553	175.00	4.70
1430	6500	650	5500	559	190.00	4.34
1540	7000	700	5920	645	204.50	4.03
1650	7500	750	6350	691	219.00	3.76
1760	8000	800	6770	737	233.50	3.52
1870	8500	850	7190	783	248.00	3.32
1980	9000	900	7620	829	263.00	3.13
2090	9500	950	8040	875	277.00	2.97
2200	10000	1000	8460	921	292.00	2.82

The viscosity is often expressed in terms of viscosimeters other than the Saybolt Universal. The formulas for the various viscosimeters are as follows:

Redwood	$K = .26t - \frac{188}{t}$	(British)	Saybolt Universal	$K = .22t - \frac{180}{t}$	American
Redwood Admiralty	$K = 2.396 - \frac{40.3}{t}$	(British)	Saybolt Furol	$K = 2.2t - \frac{203}{t}$	American
			Engler	$K = .147t - \frac{374}{t}$	German
				= Engler Degrees X 51.3	

The Barbey measures the quantity of flow per hour under constant head instead of the time for a definite quantity under varying head as do the others.

The Saybolt Furol and Redwood Admiralty are especially designed for measuring the more viscous oils and give a reading in seconds approximately one-tenth of that given for the same oil by the Saybolt Universal and Redwood respectively.

If viscosity is given at any two temperatures, the viscosity at any other temperature can be obtained by plotting the viscosity against temperature in degrees Fahrenheit on special cross section paper. The points for a given oil lie in a straight line.

Worthington Pump & Machinery Corp.

ANALYSES AND PHYSICAL PROPERTIES OF PETROLEUM OILS[1]

Source or name	Gravity, °Be	Sp gr 60°/60°F	Analysis					Btu per lb	Flash point, open cup, °F	Fire point, °F	Viscosity	
			C	H	O and N	S	H_2O				Saybolt seconds at 70°F	Engler scale at 68°F
Crude oils:												
Western	14.4	0.970	85.64	11.37	0.84	1.06	...	18,478	192	...	387	
Kern River, Calif.	15.0	0.966	.....	.....	....	0.89	0.5	18,500	102	128	...	690.0
Summerland, Calif.	15.1	0.965	.....	.....	....	0.36	1.2	18,530	100	130	...	222.1
Los Angeles City, Calif.	15.4	0.963	.....	.....	....	0.62	1.7	18,430	107	145	...	272.5
Salt Lake, Calif.	15.7	0.961	.....	.....	....	2.29	0.9	18,230	46	89	...	574.3
Western	16.4	0.957	86.58	11.61	0.74	0.82	...	18,613	172	...	380	
Western	17.4	0.950	86.37	11.30	1.14	1.60	...	18,727	230	...	250	
Sunset, Calif.	18.1	0.946	.....	.....	....	0.89	0.5	18,605	47	79	...	120.5
Coalinga, Calif.	19.4	0.938	.....	.....	....	0.48	0.4	18,550	70	93	...	80.7
Whittier, Calif.	19.4	0.938	.....	.....	....	0.61	0.0	18,810	46	84	...	34.6
Lompoc, Calif.	20.0	0.934	.....	.....	....	3.55	0.7	18,330	−1	21	...	62.5
Midcontinent	20.2	0.933	86.06	11.21	2.06	0.67	...	19,440	273	...	220	
Midway, Calif.	20.5	0.931	.....	.....	....	0.66	0.6	18,710	54	83	...	91.7
Texas	21.6	0.924	84.60	10.90	2.87	1.63	...	18,977				
Newhall, Calif.	22.1	0.921	.....	.....	....	0.35	0.2	18,890	60	83	...	118.2
Midcontinent	22.4	0.920	84.60	10.90	2.87	1.63	...	19,060	180	...	198	
Fullerton, Calif.	22.5	0.919	.....	.....	....	0.89	0.2	18,800	18	52	...	110.5
Pennsylvania	23.3	0.914	86.10	13.90	.....	0.60	...	20,752				
Midcontinent	24.2	0.909	87.93	11.27	0.19	0.41	...	19,650	264	...	188	
Coyote Hills, Calif.	24.9	0.905	.....	.....	....	1.14	tr.	18,965	27	50	...	10.5
Santa Fe Springs, Calif.	34.8	0.851	.....	.....	....	0.45	...	.....	....	...	50	
	27.9	0.888	.....	.....	....	0.54	...	.....	...	...	105	
Santa Maria, Calif.	24.9	0.905	.....	.....	....	1.93	0.1	18,710	−2	20	...	19.0
Santa Paula, Calif.	25.5	0.901	.....	.....	....	0.54	0.5	18,840	6	18	...	5.8
Sespe, Calif.	26.6	0.895	.....	.....	....	0.34	0.4	18,990	18	40	...	10.8
Eastern	31.9	0.866	86.40	12.37	1.02	0.13	...	19,890	102	...	165	
Kansas	31.9	0.866	85.40	13.07	....	....	...	20,345				
West Virginia	36.8	0.841	84.30	14.10	1.60	....	...	20,818				
Pennsylvania	37.2	0.839	.....	.....	.....	.....	...	20,560	128	180		
Ohio	39.4	0.829	85.00	13.80	0.60	0.60	...	20,752				
Eastern	40.4	0.823	82.00	14.80	3.20	0.10	...	20,300	78	...	112	
									Closed cup		Saybolt seconds	at °F
Fuel oils:												
Mexican	10.0	1.000	88.05	7.58	1.00	3.28	...	17,500	374	...	322	250
Bakersfield, Calif.	11.1	0.992	.....	.....	....	.....	1.3	18,257				
Mexican	11.9	0.987	86.90	9.36	....	3.16	...	18,050	310	...	300	250
Los Angeles City, Calif.	13.4	0.977	.....	.....	....	....	0.4	18,280				
Bakersfield, Calif.	13.6	0.975	.....	.....	....	....	...	17,600				
California	13.6	0.975	.....	.....	....	2.46	1.3	18,104				
Mexican	14.1	0.971	85.26	10.31	.....	3.94	...	18,260	208	...	92	220
California	15.0	0.966	81.52	11.61	6.92	0.55	...	18,926				
Los Angeles City, Calif.	16.4	0.957	.....	.....	.....	.....	...	18,855	196			
Midcontinent	16.7	0.955	83.22	10.16	3.74	2.83	...	18,427	190	...	74	220
Kern River, Calif.	17.4	0.950	.....	.....	....	....	...	18,845	140			
Whittier, Calif.	17.9	0.947	.....	.....	.....	.....	...	17,822	148	208		
Western	18.1	0.946	86.11	11.81	1.20	0.67	...	18,790	186	...	750	100
Whittier, Calif.	18.4	0.944	.....	.....	....	1.98	1.1	18,507				
Beaumont, Texas	18.7	0.942	86.1	12.3	....	1.60	...	20,152				
Sabine, Texas	19.5	0.937	.....	.....	....	....	...	18,662	143			
Whittier, Calif.	19.7	0.936	.....	.....	....	0.72	1.1	18,240				
Saratoga, Texas	20.6	0.930	.....	.....	....	....	...	19,665	180	242		
Coalinga, Calif.	21.1	0.927	.....	.....	....	....	...	17,117	134			
Humble, Texas	21.3	0.926	.....	.....	.....	.....	...	19,649	166	214		
Beaumont, Texas	21.6	0.924	84.6	10.9	2.87	1.63	...	19,060	180			
Spindle Top, Texas	22.0	0.922	.....	.....	....	....	...	19,663	165	219		
Mexican	22.1	0.921	.....	.....	....	....	...	18,840	162			
Saratoga, Texas	22.4	0.920	.....	.....	....	....	...	19,263	161	226		
Humble, Texas	22.4	0.920	.....	.....	....	....	...	18,040	124	228		
Midcontinent	22.4	0.920	83.26	12.41	3.83	0.59	...	19,430	181	...	389	100
Spindle Top, Texas	22.6	0.918	.....	.....	....	....	...	19,720	163	212		
Texas	24.0	0.910	87.29	12.32	....	0.43	...	19,659	375			
Texas	24.3	0.908	87.15	12.33	....	0.32	...	19,338	370			
Midcontinent	24.5	0.907	85.40	13.07	1.12	0.15	...	19,235	179	...	350	100
Louisiana	24.7	0.906	.....	.....	....	....	...	19,908	192	219		
Louisiana	24.9	0.905	.....	.....	.....	.....	...	20,193	194	233		
Beaumont, Texas	25.2	0.903	.....	.....	....	....	...	19,349	222			
Kansas	25.5	0.901	.....	.....	....	....	...	18,714	157	208		
California	27.3	0.891	.....	.....	....	....	...	18,655	257			
Pennsylvania	27.8	0.888	.....	.....	....	....	...	19,700	232	280		
Pennsylvania	28.0	0.886	84.9	13.7	1.4	....	...	19,210				
Midcontinent	28.6	0.884	84.90	13.70	1.40	0.37	...	19,312	175	...	290	100
Colorado	29.1	0.881	.....	.....	....	....	...	18,103	164	205		
Kansas	30.6	0.870	.....	.....	....	....	...	19,210	130	181		
Indiana	32.1	0.865	.....	.....	.....	.....	...	19,400	212	318		
Midcontinent	32.3	0.864	84.82	13.09	2.05	0.36	...	19,511	160	...	76	100
Midcontinent	35.9	0.845	84.36	13.21	1.09	0.32	...	19,627	154	...	42	100
West Virginia	36.8	0.841	84.3	14.1	1.6	....	...	21,240				
Pennsylvania	37.6	0.837	.....	.....	....	....	...	19,700	232	280		
Asphalt oil	13.4	0.977	.....	.....	.....	.....	...	20,442	...	376		
Gas oil	16.2	0.958	86.16	9.05	3.06	0.30	...	16,960	195	...	98	220
Steamer oil	21.1	0.927	.....	.....	.....	....	...	19,291	268	322		
Kerosene, 150°	47.4	0.791	85.16	14.33	0.51	.....	...	19,922	110			
Oil tar	....	1.150	92.00	6.13	0.22	0.33	...	17,300	485	...	418	220
Coal tar	....	1.250	89.20	4.95	5.27	0.58	...	15,800	530	...	490	220

[1] Compiled from Gebhardt, "Steam Power Plant Engineering"; Babcock & Wilcox Company, "Steam"; Heine Safety Boiler Company, "Steam Boiler Engineering"; Report of Committee on Petroleum, 1917; Rufus T. Strohm, "Oil Fuel for Steam Boilers."

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CHARACTERISTICS OF CARBURETING OILS[1]

Sample designation	Gas oil (A)	Gas oil (B)	Gas oil (C)	Heavy oil (1)	Heavy oil (2)	Heavy oil (3)	Heavy oil with some cracker tar (4)	Heavy oil containing cracker tar (5)
A.P.I. gravity at 77°F	35.1	32.5	30.3	21.1	17.2	15.4	17.3	13.9
Coke, per cent	0.22	0.62	0.02	3.98	9.05	7.10	4.62	4.11
Sulphur, per cent				1.18	2.77	0.60	0.98	0.58
Distillation test:								
Per cent by volume								
Below 400°F	1.3	1.4	0.9					
400 to 450	15.8	7.0	10.0					
450 to 500	26.0	15.3	26.0		0.0		4.5	3.9
500 to 550	20.9	18.9	31.9	1.6	2.9	2.0	11.0	12.4
550 to 600	14.8	17.4	16.7	5.2	5.6	4.3	12.4	16.0
600 to 650	8.6	13.3	8.3	9.1	22.2	12.1	16.1	15.4
650 to 700	6.7	9.5	2.5	26.8	24.2	31.9	14.4	16.0
700 to 750	5.6	8.2	3.5	14.0		32.1	30.0	20.2
Residue and loss	0.3	2.0	0.2	43.3*	44.5†	17.6	11.6	16.1
Below 600°F	78.8	60.0	85.5	6.8	9.1	6.3	27.9	32.3
Above 600°F	20.9	38.0‡	14.3	49.9	46.4	66.1	60.5	51.6
Hydrocarbon test:								
Per cent by volume								
Paraffins	73.0	45.0	44.6	49.0	32.0	34.9	48.3	35.7
Naphthenes	9.0	19.0	43.0	23.0	48.0	36.3	21.7	27.9
Aromatics	4.0	10.0	8.0	8.4	0.8	12.0	12.0	14.4
Olefins	14.0	26.0	4.4	19.6	19.2	16.8	18.0	22.0
Saturated compounds	82.0	64.0	87.6	72.0	80.0	71.2	70.0	63.6
Aromatics and unsaturates	18.0	36.0	12.4	28.0	20.0	28.8	30.0	36.4
Cracking test:								
Optimum temperature, °F	1330–1390	1380–1425	1380–1410	1350–1500	1350–1450	1300–1450	1350–1450	1300–1425
Btu in gas per gal	104,000	101,500	96,500	108,100	96,900	96,000	84,000	74,500
Btu of oil per cu ft	1,750	1,750	1,595	1,775	1,670	1,741	1,705	1,770
Cu ft of oil gas per gal	59.5	58.0	60.5	60.8	51.8	55.1	49.3	42.0

[1] Jerome J. Morgan, "American Gas Practice."
* Begins to crack at 705° F.
† Decomposes at 672° F.
‡ Includes 7.0 per cent distilling between 750° and 817° F.

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GAS OIL EFFICIENCY

Where gas oil is used for enriching carburetted water gas and no blow-run is made the following formula is generally employed to show the enriching value of the oil in B.t.u. per gallon.

$$\text{B.t.u. per Gal.} = \frac{1000\,(F - B)}{G} + OB$$

where F = B.t.u. per cu. ft. of the finished carburetted water gas.
B = B.t.u. per cu. ft. of the blue gas. (In lack of definite information frequently assumed to be 300.)
G = Gallons of oil per thousand cubic feet.
O = Cubic feet of oil gas produced per gallon of oil. (This is generally from 65 to 70 cu. ft.)

CALCULATION OF TERZIAN FACTORS FOR CARBURETTED WATER GAS MADE WITH HEAVY OIL

The development of the heavy oil process for making carburetted water gas has necessitated the conducting of plant scale tests under varied operating conditions. From the study of the operating results of these tests, a formula called the "Terzian Factor" was developed for comparing operating results, and has been successfully used. The formula for the "Terzian Factor" is:

$$\text{Terzian Factor} = \frac{K}{A} = \frac{10\,F + 100\,C}{A}$$

Where $K = 10\,F + 100\,C$
F = Gen. Fuel used, Lb./Mcf.
C = Oil used, Gal./Mcf.
A = Btu per cu. ft. Make Gas

When operating with a fairly uniform fuel and oil, operating results obtained under extremely varying conditions of operations can be successfully compared by the use of this formula; the smaller the numerical value of the Terzian Factor, the better gasification efficiencies.

It has been found in practice that the Terzian Factor, or the relation of K to the make gas Btu is practically constant under varying operating conditions, and varying amounts of generator fuel per Mcf, when producing a carburetted water gas of 400 to 700 Btu per cu. ft. calorific value, and operating with heavy oil of a fairly uniform quality.

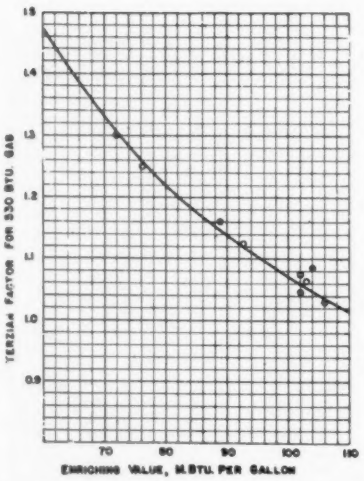
A study of heavy oil operating results of various plants for the last six years indicates that we can use the "Terzian Plant Constant" as a means of checking the plant operating results including the tar production. The formula for the "Plant Constant" is:

$$\text{Terzian Plant Constant} = \frac{K_1}{A} = \frac{10F + 100(C\text{-}T)}{A}$$

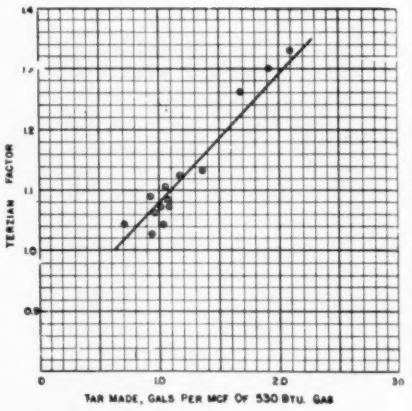
Where K_1 = Plant Constant
T = Tar Made gals./Mcf
F. C. & A. are as shown above

The "Plant Constant" varies between .88 and .92, primarily due to the quality of the heavy oil used. Oils of high enrichment value give a low "Plant Constant," and oils of low enriching value give the higher figure. There is also a slight variation between different plants, even though the quality of the oil might be practically the same. This variation is due to certain plant characteristics such as the quality of fuel used, technique of operation, miscellaneous plant equipment, etc.

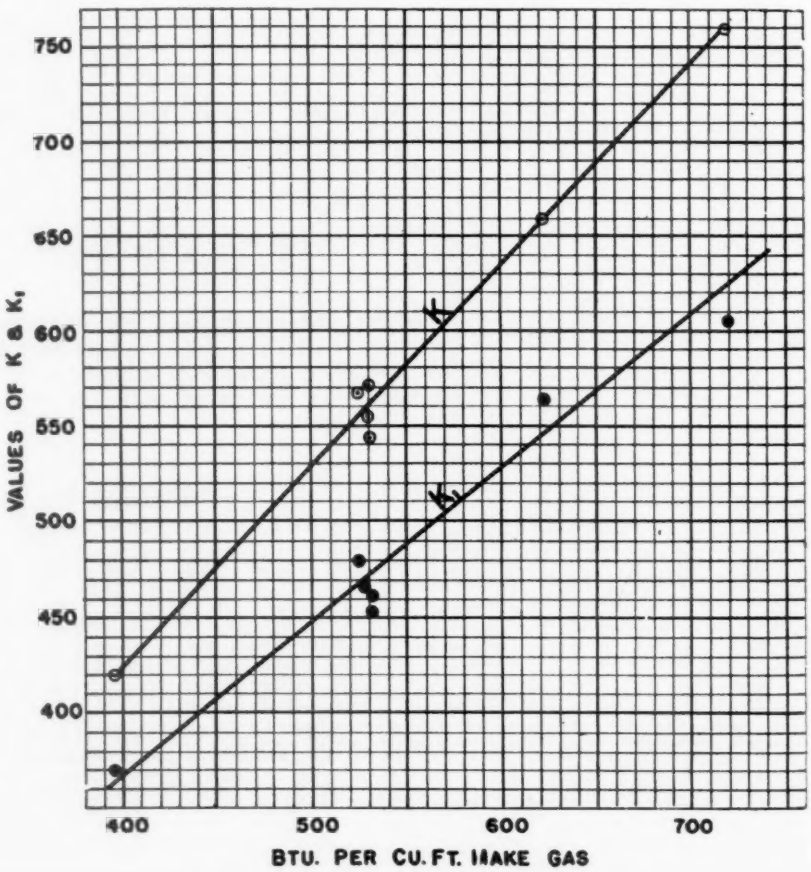
H. G. Terzian, 1936 AGA Production Conference.



Typical Relation of Terzian Factor to Enriching Value of Heavy Oil when Making 530 Btu gas.



Typical Relation of Terzian Factor to Gals. Tar Made per Mcf of 530 Btu Gas When Using Heavy Oils of Varying Enriching Qualities.



Relation of Make Gas Btu to K and K_1 Typical Values.

TANK FORMULAS

The following formulas have been selected to facilitate the rapid calculation of capacities of various types of storage tanks in gallons and barrels.

Uniform Notations:

B = Capacity of each dished head in United States gallons.
B_2 = Total capacity of both dished heads in United States gallons.
C_B = Total capacity of tank in barrels (of 42 United States gallons).
C_G = Total capacity of tank in United States gallons.
C_{GF} = Capacity of cylindrical portion of tank in United States gallons per foot length. (Flat heads.)
D = Inside diameter of tank in feet.
G = Liquid contents of partially filled tank in United States gallons.
L = Length of cylindrical portion of tank in feet.
b = Dish of head, bead line to inside of plate (height of arc) in inches.
d = Inside diameter of tank in inches.
h = Depth or height of liquid in tank in inches.
l = Length of cylindrical portion of tank in inches.
r = Radius of dished head (where different from tank diameter) in inches.
k = Per cent of total capacity of horizontal tanks.

Capacity of Vertical Cylindrical Tanks with Flat Heads

R = Inside radius of tank in feet.
H = Height of liquid in feet.
C_{GF} = Capacity in United States gallons, per foot depth = $23.501\ R^2$.
C_G = Total capacity in United States gallons = $23.501R^2H$.
C_B = Total capacity in barrels (of 42 United States gallons) = $0.56\ R^2H$.

Capacity of Horizontal Cylindrical Tanks with Flat Heads

C_{GF} = Capacity in United States gallons per foot length = $0.0408d^2$.
C_G = Total capacity in United States gallons = $0.0034d^2l$.
C_G = Total capacity in United States gallons = $5.875D^2L$.
C_B = Total capacity in barrels (of 42 United States gallons) = $0.14\ D^2L$.

Capacity of Horizontal Cylindrical Tanks with Dished Heads

(where radius of dished head equals diameter of tank)

C_G = Total capacity in United States gallons = $0.0034d^2l + 0.0004664d^3$.
C_G = Total capacity in United States gallons = $5.875D^2L + 0.806D^3$.
C_B = Total capacity in barrels (of 42 United States gallons) = $0.14D^2L + 0.019D^3$.

Capacity of Dished Head of any Radius

B = Capacity of each dished head in United States gallons = $0.0045333b^2\ (3r - b)$.

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Capacity of Spherical Tanks

C_G = Total capacity in United States gallons = $0.0022666d^3$.
C_G = Total capacity in United States gallons = $3.9168D^3$.
C_B = Total capacity in barrels (of 42 United States gallons) = $0.093257D^3$.

Liquid Contents of partially filled Tanks

Horizontal Cylindrical Tanks with Flat Heads:

G = Liquid contents in United States gallons

$$= \frac{1}{231}\left[0.004363\ d^2\ \mathrm{Cos}^{-1}\ \frac{d-2h}{d} - \frac{d-2h}{2}\sqrt{h(d-h)}\right].$$

The notation $\mathrm{Cos}^{-1}\ \frac{d-2h}{d}$ (read inverse cosine of $\frac{d-2h}{d}$, or arc cosine $\frac{d-2h}{d}$) means the angle (in degrees) whose cosine is equal to $\frac{d-2h}{d}$.

The use of this inverse function can best be illustrated by an example:

Find the number of gallons contained in a horizontal cylindrical tank with flat heads, if the tank inside diameter is 100 inches, the length 50 inches, and the tank is filled with liquid to a depth of 10 inches. Substituting in the above formula,

$$G = \frac{50}{231}\left[0.004363(100)^2\mathrm{Cos}^{-1}\ \frac{100-20}{100} - \frac{100-20}{2}\sqrt{10(100-10)}\right].$$

$$G = 0.21645\left[43.63\ \mathrm{Cos}^{-1}\ 0.80 - 40\sqrt{900}\right].$$

But, as stated above, $\mathrm{Cos}^{-1}\ 0.80$ means "the angle of

CAPACITIES OF DISHED HEADS

The type of dished heads and the total capacity of two such heads for tanks of various diameters may be obtained from the following:

	Standard Dish Type			Shallow Dish Type		
Diameter of Tank	Dish Radius	Height of Bulge*	Capacity 2 Heads-Gallons	Dish Radius	Height of Bulge*	Capacity 2 Heads-Gallons
5'-6"	5'-6"	9¼"	140	10'-0"	5¼"	80
6'-0"	6'-0"	10¼"	180	10'-0"	6¼"	110
6'-6"	6'-6"	11 "	230	10'-0"	7¼"	150
7'-0"	7'-0"	11¾"	285	10'-0"	8¼"	200
7'-6"	7'-6"	12½"	350	16'-5"	6 "	165
8'-0"	8'-0"	13¼"	425	16'-5"	6¾"	210
8'-6"	8'-6"	14¼"	510	16'-5"	7½"	265
9'-0"	9'-0"	15 "	605	16'-5"	8¼"	330
9'-6"	9'-6"	15¾"	710	16'-5"	9 "	405
10'-0"	10'-0"	16½"	825	25'-0"	6¾"	340
10'-6"	10'-6"	17½"	955	25'-0"	7½"	420
11'-0"	11'-0"	18¼"	1100	25'-0"	8¼"	500
12'-0"	12'-0"	20 "	1435	25'-0"	9½"	690

* The "Height of Bulge" is measured from a plane perpendicular to the axis of the tank and passing through the end of the cylindrical section of the head flange to the center point on the outside of the head. The length of the cylindrical part of the tank plus twice the height of the bulge will equal the total length of the tank measured along its axis.

The material for this table was obtained from "Steel Plates," a handbook compiled by Bethlehem Steel Co.

which the cosine is 0.80." From a table of natural cosines the angle is found to be 36° 52′ or 36.87°. Substituting this value for Cos^{-1} 0.80 we have,

$G = 0.21645\ (43.63 \times 36.87 - 1200)$,
$G = 0.21645 \times 408.6$,
$G = 88.45$ gallons.

Note: In calculating liquid contents of partially filled tanks, use formula for tanks up to half full. For tanks over half full, calculate capacity of unfilled portion and subtract from capacity of full tank.

Spherical Tanks:

G = Liquid contents in United States gallons
$= 0.0022666h^2(3d - 2h)$.

Liquid Contents of partially filled Horizontal Cylindrical Tanks—with Flat Heads (by use of Tables 2 and 3).

(1) Tank less than half full:

In order to find the gallons of liquid in a horizontal cylindrical tank with flat heads when tank is less than half full:

Find the total capacity of the tank, C_G, either by calculating from the formulas or by finding the capacity per foot length, C_{GF}, from Table 2 and multiplying by the length of the tank in feet.

Divide the depth of liquid, h, by the inside diameter of the tank, d, and by referring to Table 3 find the k corresponding to the h/d just found.

The United States gallons of liquid in the tank are then,

$$\text{United States gallons} = \frac{C_G \times k}{100}.$$

Example:

d = 96 inches;
L = 30.5 feet;
h = 32 inches.

From Table 2, $C_{GF} = 376.01$;
then $C_G = C_{GF}L = 376.01 \times 30.5 = 11{,}468$ gallons;

$$\frac{h}{d} = \frac{32}{96} = 0.333.$$

From Table 3, $k = 29.1391$;
therefore, United States gallons in tank $=$

$$\frac{11{,}468 \times 29.1391}{100} = 3341.7.$$

(2) Tank over half full:

To find the liquid contents of a tank over half full, let h′ = depth of *unfilled portion*. The calculation should then proceed as for a tank less than half full using h′ instead of h. The result obtained will then be the capacity of the *unfilled portion* of the tank and must be subtracted from the total capacity of the tank, C_G, to find the quantity of liquid in the tank.

Table 2

CAPACITIES OF HORIZONTAL CYLINDRICAL TANKS IN UNITED STATES GALLONS PER FOOT LENGTH FLAT AND OF DISHED HEADS (WHERE r=d)

1 gallon = 231 cubic inches = 0.13368 cubic foot
1 cubic foot = 7.4805 gallons

Inside diameter of tank in inches	Capacity of cylindrical portion of tank per foot length	Total capacity of both dished heads	Inside diameter of tank in inches	Capacity of cylindrical portion of tank per foot length	Total capacity of both dished heads	Inside diameter of tank in inches	Capacity of cylindrical portion of tank per foot length	Total capacity of both dished heads
d	C_{GF}	B_1	d	C_{GF}	B_1	d	C_{GF}	B_1
12	5.88	0.81	48	94.00	51.58	84	287.88	276.45
13	6.90	1.02	49	97.96	54.87	85	294.78	286.44
14	8.00	1.26	50	102.00	58.30	86	301.76	296.67
15	9.18	1.57	51	106.12	61.87	87	308.82	307.14
16	10.44	1.91	52	110.32	65.58	88	315.96	317.85
17	11.79	2.29	53	114.61	69.44	89	323.18	328.81
18	13.22	2.72	54	118.97	73.44	90	330.48	340.02
19	14.73	3.20	55	123.42	77.60	91	337.86	351.48
20	16.32	3.73	56	127.95	81.91	92	345.33	363.18
21	17.99	4.32	57	132.56	86.38	93	352.88	375.16
22	19.75	4.97	58	137.25	91.00	94	360.51	387.40
23	21.58	5.67	59	142.02	95.79	95	368.22	399.89
24	23.50	6.45	60	146.88	100.75	96	376.01	412.65
25	25.50	7.29	61	151.82	105.87	97	383.89	425.68
26	27.58	8.20	62	156.84	111.16	98	391.84	438.99
27	29.74	9.18	63	161.94	116.63	99	399.88	452.56
28	31.99	10.24	64	167.12	122.27	100	408.00	466.41
29	34.31	11.38	65	172.38	128.09	101	416.20	480.55
30	36.72	12.59	66	177.72	134.09	102	424.48	494.96
31	39.21	13.89	67	183.15	140.28	103	432.85	509.66
32	41.78	15.28	68	188.66	146.66	104	441.29	524.65
33	44.43	16.76	69	194.25	153.22	105	449.82	539.93
34	47.16	18.33	70	199.92	159.98	106	458.43	555.51
35	49.98	20.00	71	205.67	166.93	107	467.12	571.38
36	52.88	21.76	72	211.51	174.09	108	475.89	587.55
37	55.86	23.63	73	217.42	181.44	109	484.74	604.02
38	58.92	25.59	74	223.42	189.00	110	493.68	620.80
39	62.06	27.67	75	229.50	196.77	111	502.70	637.88
40	65.28	29.85	76	235.66	204.74	112	511.80	655.28
41	68.58	32.15	77	241.90	212.93	113	520.98	672.99
42	71.97	34.56	78	248.23	221.34	114	530.24	691.01
43	75.44	37.08	79	254.63	229.96	115	539.58	709.36
44	78.99	39.73	80	261.12	238.80	116	549.00	728.02
45	82.62	42.50	81	267.69	247.87	117	558.51	747.01
46	86.33	45.40	82	274.34	257.17	118	568.10	766.33
47	90.13	48.42	83	281.07	266.69	119	577.77	785.98
						120	587.52	805.96

Capacity for Flat Heads = $C_{GF}L$ Capacity for Dished Heads = $C_{GF}L + B_1$

Table 3

TABLE FOR GAGING HORIZONTAL CYLINDRICAL TANKS WITH FLAT HEADS—PER CENT OF TOTAL CAPACITY—k

$\frac{h}{d}$	k	$\frac{h}{d}$	k	$\frac{h}{d}$	k	$\frac{h}{d}$	k
.001	.0053	.043	1.4940	.085	4.0980	.127	7.3836
.002	.0152	.044	1.5460	.086	4.1694	.128	7.4686
.003	.0279	.045	1.5986	.087	4.2409	.129	7.5539
.004	.0429	.046	1.6515	.088	4.3128	.130	7.6393
.005	.0600	.047	1.7052	.089	4.3852	.131	7.7251
.006	.0788	.048	1.7594	.090	4.4579	.132	7.8112
.007	.0992	.049	1.8141	.091	4.5310	.133	7.8975
.008	.1212	.050	1.8692	.092	4.6043	.134	7.9841
.009	.1445	.051	1.9250	.093	4.6781	.135	8.0709
.010	.1692	.052	1.9813	.094	4.7522	.136	8.1582
.011	.1952	.053	2.0382	.095	4.8267	.137	8.2456
.012	.2223	.054	2.0955	.096	4.9016	.138	8.3332
.013	.2507	.055	2.1533	.097	4.9767	.139	8.4212
.014	.2800	.056	2.2115	.098	5.0523	.140	8.5094
.015	.3104	.057	2.2703	.099	5.1282	.141	8.5979
.016	.3419	.058	2.3296	.100	5.2044	.142	8.6867
.017	.3743	.059	2.3894	.101	5.2810	.143	8.7757
.018	.4077	.060	2.4496	.102	5.3579	.144	8.8651
.019	.4421	.061	2.5103	.103	5.4351	.145	8.9546
.020	.4773	.062	2.5716	.104	5.5126	.146	9.0443
.021	.5134	.063	2.6332	.105	5.5905	.147	9.1343
.022	.5503	.064	2.6952	.106	5.6688	.148	9.2246
.023	.5881	.065	2.7578	.107	5.7474	.149	9.3153
.024	.6267	.066	2.8209	.108	5.8262	.150	9.4061
.025	.6660	.067	2.8843	.109	5.9054	.151	9.4971
.026	.7061	.068	2.9482	.110	5.9850	.152	9.5884
.027	.7470	.069	3.0125	.111	6.0648	.153	9.6799
.028	.7886	.070	3.0772	.112	6.1449	.154	9.7717
.029	.8310	.071	3.1424	.113	6.2254	.155	9.8638
.030	.8742	.072	3.2081	.114	6.3062	.156	9.9560
.031	.9179	.073	3.2740	.115	6.3872	.157	10.0485
.032	.9624	.074	3.3405	.116	6.4687	.158	10.1414
.033	1.0075	.075	3.4073	.117	6.5503	.159	10.2343
.034	1.0534	.076	3.4747	.118	6.6323	.160	10.3275
.035	1.0998	.077	3.5423	.119	6.7147	.161	10.4211
.036	1.1469	.078	3.6104	.120	6.7972	.162	10.5147
.037	1.1947	.079	3.6789	.121	6.8802	.163	10.6086
.038	1.2431	.080	3.7478	.122	6.9633	.164	10.7029
.039	1.2921	.081	3.8170	.123	7.0469	.165	10.7972
.040	1.3417	.082	3.8867	.124	7.1307	.166	10.8919
.041	1.3919	.083	3.9568	.125	7.2147	.167	10.9868
.042	1.4427	.084	4.0273	.126	7.2991	.168	11.0819

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Table 3—Continued

$\frac{h}{d}$	k	$\frac{h}{d}$	k	$\frac{h}{d}$	k	$\frac{h}{d}$	k
.169	11.1771	.211	15.3697	.253	19.8815	.295	24.6495
.170	11.2728	.212	15.4737	.254	19.9923	.296	24.7657
.171	11.3685	.213	15.5778	.255	20.1033	.297	24.8820
.172	11.4645	.214	15.6821	.256	20.2143	.298	24.9984
.173	11.5606	.215	15.7866	.257	20.3255	.299	25.1149
.174	11.6571	.216	15.8914	.258	20.4369	.300	25.2315
.175	11.7538	.217	15.9962	.259	20.5483	.301	25.3483
.176	11.8505	.218	16.1013	.260	20.6600	.302	25.4652
.177	11.9477	.219	16.2066	.261	20.7718	.303	25.5822
.178	12.0450	.220	16.3120	.262	20.8837	.304	25.6992
.179	12.1425	.221	16.4175	.263	20.9957	.305	25.8165
.180	12.2403	.222	16.5232	.264	21.1079	.306	25.9337
.181	12.3382	.223	16.6291	.265	21.2202	.307	26.0511
.182	12.4364	.224	16.7352	.266	21.3326	.308	26.1686
.183	12.5347	.225	16.8415	.267	21.4453	.309	26.2863
.184	12.6332	.226	16.9480	.268	21.5580	.310	26.4039
.185	12.7320	.227	17.0545	.269	21.6708	.311	26.5218
.186	12.8309	.228	17.1612	.270	21.7839	.312	26.6397
.187	12.9301	.229	17.2682	.271	21.8969	.313	26.7578
.188	13.0296	.230	17.3753	.272	22.0102	.314	26.8759
.189	13.1291	.231	17.4825	.273	22.1236	.315	26.9941
.190	13.2290	.232	17.5899	.274	22.2371	.316	27.1125
.191	13.3290	.233	17.6975	.275	22.3507	.317	27.2309
.192	13.4291	.234	17.8052	.276	22.4645	.318	27.3494
.193	13.5296	.235	17.9131	.277	22.5784	.319	27.4681
.194	13.6302	.236	18.0212	.278	22.6924	.320	27.5868
.195	13.7310	.237	18.1294	.279	22.8065	.321	27.7057
.196	13.8320	.238	18.2378	.280	22.9209	.322	27.8246
.197	13.9332	.239	18.3462	.281	23.0352	.323	27.9437
.198	14.0345	.240	18.4550	.282	23.1498	.324	28.0627
.199	14.1361	.241	18.5638	.283	23.2644	.325	28.1820
.200	14.2379	.242	18.6727	.284	23.3791	.326	28.3013
.201	14.3399	.243	18.7819	.285	23.4941	.327	28.4207
.202	14.4420	.244	18.8912	.286	23.6090	.328	28.5402
.203	14.5443	.245	19.0007	.287	23.7241	.329	28.6599
.204	14.6468	.246	19.1102	.288	23.8395	.330	28.7795
.205	14.7495	.247	19.2199	.289	23.9549	.331	28.8992
.206	14.8525	.248	19.3298	.290	24.0703	.332	29.0192
.207	14.9555	.249	19.4399	.291	24.1859	.333	29.1391
.208	15.0587	.250	19.5501	.292	24.3017	.334	29.2592
.209	15.1621	.251	19.6605	.293	24.4174	.335	29.3794
.210	15.2659	.252	19.7710	.294	24.5334	.336	29.4996

Table 3—Concluded

$\frac{h}{d}$	k	$\frac{h}{d}$	k	$\frac{h}{d}$	k	$\frac{h}{d}$	k
.337	29.6199	.378	34.6221	.419	39.7321	.460	44.9125
.338	29.7403	.379	34.7456	.420	39.8577	.461	45.0394
.339	29.8608	.380	34.8691	.421	39.9834	.462	45.1664
.340	29.9814	.381	34.9927	.422	40.1092	.463	45.2933
.341	30.1021	.382	35.1165	.423	40.2350	.464	45.4203
.342	30.2228	.383	35.2402	.424	40.3608	.465	45.5473
.343	30.3437	.384	35.3640	.425	40.4866	.466	45.6743
.344	30.4645	.385	35.4879	.426	40.6125	.467	45.8014
.345	30.5856	.386	35.6119	.427	40.7384	.468	45.9284
.346	30.7067	.387	35.7359	.428	40.8645	.469	46.0555
.347	30.8279	.388	35.8599	.429	40.9904	.470	46.1826
.348	30.9491	.389	35.9840	.430	41.1165	.471	46.3096
.349	31.0705	.390	36.1082	.431	41.2426	.472	46.4368
.350	31.1918	.391	36.2324	.432	41.3687	.473	46.5639
.351	31.3134	.392	36.3567	.433	41.4949	.474	46.6911
.352	31.4350	.393	36.4810	.434	41.6211	.475	46.8183
.353	31.5566	.394	36.6055	.435	41.7474	.476	46.9454
.354	31.6783	.395	36.7299	.436	41.8735	.477	47.0726
.355	31.8002	.396	36.8544	.437	41.9998	.478	47.1998
.356	31.9220	.397	36.9789	.438	42.1261	.479	47.3269
.357	32.0440	.398	37.1036	.439	42.2526	.480	47.4541
.358	32.1661	.399	37.2282	.440	42.3789	.481	47.5815
.359	32.2882	.400	37.3530	.441	42.5053	.482	47.7087
.360	32.4104	.401	37.4778	.442	42.6318	.483	47.8359
.361	32.5327	.402	37.6026	.443	42.7583	.484	47.9632
.362	32.6550	.403	37.7275	.444	42.8847	.485	48.0904
.363	32.7774	.404	37.8524	.445	43.0113	.486	48.2177
.364	32.8999	.405	37.9774	.446	43.1379	.487	48.3450
.365	33.0225	.406	38.1025	.447	43.2646	.488	48.4722
.366	33.1451	.407	38.2275	.448	43.3911	.489	48.5996
.367	33.2678	.408	38.3526	.449	43.5178	.490	48.7269
.368	33.3906	.409	38.4778	.450	43.6445	.491	48.8542
.369	33.5134	.410	38.6030	.451	43.7712	.492	48.9814
.370	33.6363	.411	38.7283	.452	43.8979	.493	49.1087
.371	33.7593	.412	38.8537	.453	44.0245	.494	49.2360
.372	33.8823	.413	38.9790	.454	44.1514	.495	49.3634
.373	34.0054	.414	39.1044	.455	44.2782	.496	49.4907
.374	34.1287	.415	39.2298	.456	44.4050	.497	49.6180
.375	34.2519	.416	39.3553	.457	44.5318	.498	49.7453
.376	34.3752	.417	39.4809	.458	44.6587	.499	49.8727
.377	34.4986	.418	39.6064	.459	44.7856	.500	50.0000

CONSUMERS' METERS

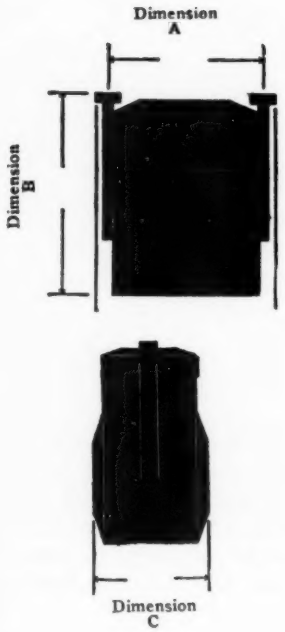
CAPACITIES, WEIGHTS, ETC., OF TINNED-STEEL CASE METERS

(Now regularly manufactured)

The dimensions are expressed in inches.
The rated gas capacity is given in cubic feet an hour at ½-inch differential

Size and Type	Rated Capacity	Connections Threaded for Iron Pipe	Dimensions A	Dimensions B	Dimensions C	Proving Circle Cu. Ft.	Cu. Ft. per Rev. of Tang.	Approx. Shipping Weight Pounds
2B	65	½″	9″	11 31/32″	6 11/16″	1	1/20	9
5B	150	½″	11¼″	16¼″	9 3/16″	2	1/6	16¼
10B	300	¾″	13⅝″	18½″	11¼″	5	5/17	25
20B	450	1″	16 1/16″	22″	12 7/16″	5	5/11	39
30B	600	1¼″	18¼″	26⅛″	15″	5	5/7	54
60B	1300	1½″	24″	31⅜″	21″	10	1 3/7	220
100B	1800	2″	27″	36¼″	23¾″	20	2½	258
200B	3200	2½″	33¾″	43¼″	30¾″	50	5	430
5M	210	½″	11¼″	16 7/16″	9½″	2	1/6	18
5MS	300	¾″	11⅜″	16½″	9½″	2	1/6	19
10M	400	¾″	12 5/16″	17 11/16″	10⅞″	5	5/18	23
20A	600	1″	16″	22⅛″	14½″	5	¼	42
30M	900	1¼″	18½″	25″	16⅛″	5	5/8	57
60M	1700	1½″	25⅜″	33 5/16″	20⅝″	20	2	142
150A	3400	2½″	32 3/16″	42 11/16″	27½″	50	5	355
6C	600	1¼″	14⅜″	19¾″	13¼″	10	½	57
11C	1100	2″	19 11/16″	27¾″	16⅞″	10	1 1/9	131½
25C	2500	2½″	25⅜″	34″	24½″	20	2 6/7	267
40C	4000	3″	29 1/16″	38½″	29¼″	50	5	352
60C	6000	4″	36¾″	45″	35⅜″	100	10	523

All "C" type meters are equipped with galvanized straight threaded nipples of standard pipe thread and will connect direct to standard iron pipe service fittings, requiring no meter connections or special threads.



SPECIFICATIONS OF AMERICAN METRIC IRONCASE METERS

Type	Maximum working pressure, pounds	Type and size of connections	Low pressure capacities cubic feet an hour: ½″ water differential	Low pressure capacities cubic feet an hour: 2″ water differential	Approx. shipping weight pounds each
5–B AL	5	¾″, 1″ or 1½″ M. C.	175	370	23½
5–B	5	1″ or 1¼″ M. C.	175	370	41
5–B	25	1″ Male thread	175	370	45
10–B	5	1″ or 1¼″ M. C.	250	570	50
10–B	100	1″ F. P. T.	250	570	95
20–B	10	1¼″ or 1½″ M. C.	350	700	90
25–B	10	1¼″ M. C.	400	900	110
25–B	100	1¼″ F. P. T.	400	900	125
25–B	250	1¼″ F. P. T.	400	900	185
25–B	500	1¼″ F. P. T.	400	900	185
30–B	15	1½″ M. C.	550	1100	155
30–B	250	2″ Flange	550	1100	380
35–B	15	1½″ M. C.	650	1500	175
35–B	100	1½″ F. P. T.	650	1500	185
60–B	20	2″ M. C.	950	2000	290
60–B	100	2″ F. P. T.	950	2000	300
60–B	250	2″ F. P. T.	950	2000	415
80–B	20	2″ F. P. T.	1200	2500	315
80–B	100	2″ F. P. T.	1200	2500	325
80–B AL	100	2″ F. P. T.	1200	2500	325
80–B	250	2″ F. P. T.	1200	2500	430
80–B	500	2″ F. P. T.	1200	2500	450
250–B	75	4″ F. P. T.	3000	6000	530
250–B	100	4″ F. P. T.	3000	6000	540
250–B AL	100	4″ F. P. T.	3000	6000	160
250–B	250	4″ F. P. T.	3000	6000	750
500–B	75	4″ F. P. T.	4800	10000	960
500–B	100	4″ F. P. T.	4800	10000	970
500–B	250	4″ F. P. T.	4800	10000	1355

METRIC IRONCASE METERS

Table of recommended maximum hourly rates in cubic feet expressed at four-ounce base pressure when measuring gas at high pressure.

Specific gravity of gas, 0.6

Gage pressure	Type of Meter 20-B	25-B	30-B	35-B	60-B	80-B	250-B	500-B
4 oz.	700	900	1100	1500	2000	2500	6000	10000
5 lb.	900	1100	1400	1900	2500	3100	7500	12500
10 lb.	1000	1300	1600	2200	3000	3700	8900	15000
15 lb.	.....	1500	1900	2600	3400	4300	10000	17000
20 lb.	.....	1700	2100	2900	3800	4800	12000	19000
30 lb.	.....	2100	2600	3500	4700	5800	14000	23000
50 lb.	.....	2800	3400	4600	6100	7700	18000	31000
75 lb.	.....	3500	4300	5900	7900	9900	24000	39000
100 lb.	.....	4300	5200	7100	9500	12000	28000	47000
150 lb.	.....	5600	6800	.....	12000	15000	37000	62000
200 lb.	.....	6800	8400	.....	15000	19000	46000	76000
250 lb.	.....	8100	9900	.....	18000	22000	54000	90000

EMCO DOMESTIC IRON METERS

Size	Working Press. Lbs.	Size Connection	Rating .60 Sp. Gr. Gas 5" Absorption C.F.H.	Cu. Ft. Per Rev. Proving Hand	Distance Between Center Line of Connections	Height	Shipping Weight Lbs.
#0 Curb Box	10	1¼" F.P.T.	175	2	4¾"	15 11/16"	40
#1 Std.	10	45 Lt, 20 Lt, 30 Lt, Sprague #2, 1¼" Whitworth	275	2	7"	14 3/16"	43
#2 Std.	10	45 Lt.	415	5	8"	16 11/16"	60
#2 Curb Box	10	1½" F.P.T.	415	5	7½"	19 3/16"	70

ROCKWELL-EMCO DOMESTIC ALUMINUM METERS

#0	10	1¼" M.P.T., 20 Lt, 30 Lt, Sprague #1 & 1-A, 1¼" Whitworth	175	2	6"	12 11/16"	18
#00	10	5 Lt, 10 Lt, 20 Lt, 1¼" M.P.T., #1 Sprague, 1¼" Whitworth	150	2	6"	11 9/32"	9

EMCO INDUSTRIAL AND LARGE CAPACITY METERS

Size	Working Press. Lbs.	Size Connections	Rating 60 Sp. Gr. Gas .5 Absorption	Rating 60 Sp. Gr. Gas 2.0 Absorption	Cu. Ft. Per Rev. Proving Hand	Length	Height	Shipping Weight Lbs.
#2½	75	2" F.P.T.	850	1800	10	20¾"	25¼"	227
	100	2" F.P.T.	850	1800	10	20¾"	25 11/16"	368
	200	2" F.P.T.	850	1800	10	20¾"	25 11/16"	380
	500	2" F.P.T.	850	1800	10	21¾"	26⅛"	420
#3	75	3" F.P.T.	1200	2500	10	22½"	27 7/16"	305
	100	3" F.P.T.	1200	2500	10	22½"	28¼"	425
	200	3" F.P.T.	1200	2500	10	22½"	28¼"	435
	500	3" F.P.T.	1200	2500	10	22⅞"	28¾"	450
#4	75	4" F.P.T.	2250	5000	10	27¼"	32⅞"	506
	100	4" F.P.T.	2250	5000	10	28"	32 11/16"	682
	200	4" F.P.T.	2250	5000	10	28"	32 11/16"	1080
	500	4" F.P.T.	2250	5000	10	29¼"	34¼"	1175
#4½	75	4" F.P.T.	3000	6000	10	33¼"	42 7/16"	675
#5	50	4" F.P.T.	5000	10000	100	40"	51¼"	1040

INSTRUCTIONS FOR ACCURATE PROOF TESTING OF GAS METERS

To arrive at accurate results in proof-testing gas meters necessitates close attention to a great many details. Merely connecting the meter to a prover and passing a small quantity of air or gas through, without strict regard to the following rules, will result in an approximation only and is not a correct proof test.

To proof test a meter accurately the prover must be mathematically correct, perfectly level, duly counterpoised and adjusted so as to give uniform pressure from top to bottom during the movement of the bell in the tank. Provers are commonly adjusted to throw a pressure of one and one-half inches water column. The liquid in the prover, the air or gas in the bell and also the meter to be proof tested must all be uniform in temperature with the air of the room in which the tests are to be made and all of these temperatures must be kept uniform during the entire test.

The meter or meters to be proof tested should be brought to the proving room at least five hours or if possible for a longer period before making tests, thereby giving them an opportunity to become adjusted to room temperature. When these conditions have been met, the test may proceed.

The inlet of the meter is connected to the prover hose by means of a suitable connection. The connections and meter are then tested for leaks by opening the outlet valve on the prover connections, placing the palm of the hand over the meter outlet, and then closing the valve. If the siphon gauge shows a drop in pres-

sure, it is an indication of a leak in the connection or in the meter. The leak can be located by means of soapsuds.

Attach the proper check cap on the meter outlet and pass enough air from the prover through the meter to bring the test hand, while on the up run, directly over a division or mark on the proving circle.

Fill the prover bell and carefully adjust the zero scale reading by means of the prover slide valve. Open the valve on the connection and pass a sufficient volume from the prover through the meter to cause the test hand to make one full revolution. Exercise care to insure that the test hand is stopped exactly over the mark from which it started at the beginning of the test. The reading on the prover scale is noted and from these data the proof is determined. If the meter is to be proof tested at the open rate, the procedure is the same as with the check rate test with the exception that the meter outlet is unrestricted. The maximum rate at which the prover delivers air through the hose and connections to the meter at the open-rate test depends upon the capacity of the meter, pressure in the prover, and size of connections from the interior of the prover to the meter.

Differential Test

The differential test of meters at a definite check rate is the supplementary test which is used as a final check to determine the absence of avoidable internal friction or binds in meters before final proof. For this purpose the differential, which is the difference in pressure between the inlet and outlet of the meter, is indicated in inches of water on a sensitive draft gauge.

At a very low rate of flow the differential is produced primarily by internal friction. In a properly assembled meter this internal friction depends upon the flexibility of the diaphragms, the relative tightness of the stuffing boxes, and to a certain extent, upon the clearance between the moving parts. In some cases where heavier diaphragms or tighter packing of the stuffing boxes are specified, a slightly higher differential will result. Consequently, for any particular size of meter, the differential limits will depend upon the specifications.

Any increase in differential resulting from binds, excessive friction in the stuffing boxes, or stiff diaphragm leather should be eliminated before final proof. This precaution is of basic importance because if internal friction is reduced by wear after a meter is placed in service, the proof may be affected.

At low rates of flow, the differential between meter inlet and outlet pressures may be about 0.10 inches of water.

American Meter Company.

PERCENTAGE OF ERROR TABLE

	2 cubic feet passed by meter		5 cubic feet passed by meter		10 cubic feet passed by meter		20 cubic feet passed by meter	
	Prover	Error	Prover	Error	Prover	Error	Prover	Error
FAST	1.80	+11.11	4.50	+11.11	9.00	+11.11	18.00	+11.11
	1.81	+10.50	4.52	+10.62	9.05	+10.50	18.10	+10.50
	1.82	+ 9.89	4.55	+ 9.89	9.10	+ 9.89	18.20	+ 9.89
	1.83	+ 9.29	4.58	+ 9.17	9.15	+ 9.29	18.30	+ 9.29
	1.84	+ 8.70	4.60	+ 8.70	9.20	+ 8.70	18.40	+ 8.70
	1.85	+ 8.11	4.62	+ 8.20	9.25	+ 8.11	18.50	+ 8.11
	1.86	+ 7.53	4.65	+ 7.53	9.30	+ 7.53	18.60	+ 7.53
	1.87	+ 6.95	4.68	+ 6.84	9.35	+ 6.95	18.70	+ 6.95
	1.88	+ 6.38	4.70	+ 6.38	9.40	+ 6.38	18.80	+ 6.38
	1.89	+ 5.82	4.72	+ 5.93	9.45	+ 5.82	18.90	+ 5.82
	1.90	+ 5.26	4.75	+ 5.26	9.50	+ 5.26	19.00	+ 5.26
	1.91	+ 4.71	4.78	+ 4.60	9.55	+ 4.71	19.10	+ 4.71
	1.92	+ 4.17	4.80	+ 4.17	9.60	+ 4.17	19.20	+ 4.17
	1.93	+ 3.63	4.82	+ 3.73	9.65	+ 3.63	19.30	+ 3.63
	1.94	+ 3.09	4.85	+ 3.09	9.70	+ 3.09	19.40	+ 3.09
	1.95	+ 2.56	4.88	+ 2.46	9.75	+ 2.56	19.50	+ 2.56
	1.96	+ 2.04	4.90	+ 2.04	9.80	+ 2.04	19.60	+ 2.04
	1.97	+ 1.52	4.92	+ 1.63	9.85	+ 1.52	19.70	+ 1.52
	1.98	+ 1.01	4.95	+ 1.01	9.90	+ 1.01	19.80	+ 1.01
	1.99	+ 0.50	4.98	+ 0.40	9.95	+ 0.50	19.90	+ 0.50
Correct	2.00	0.00	5.00	0.00	10.00	0.00	20.00	0.00
SLOW	2.01	—0.50	5.02	—0.40	10.05	—0.50	20.10	—0.50
	2.02	—0.99	5.05	—0.99	10.10	—0.99	20.20	—0.99
	2.03	—1.48	5.08	—1.57	10.15	—1.48	20.30	—1.48
	2.04	—1.96	5.10	—1.96	10.20	—1.96	20.40	—1.96
	2.05	—2.44	5.12	—2.34	10.25	—2.44	20.50	—2.44
	2.06	—2.91	5.15	—2.91	10.30	—2.91	20.60	—2.91
	2.07	—3.38	5.18	—3.47	10.35	—3.38	20.70	—3.38
	2.08	—3.85	5.20	—3.85	10.40	—3.85	20.80	—3.85
	2.09	—4.31	5.22	—4.21	10.45	—4.31	20.90	—4.31
	2.10	—4.76	5.25	—4.76	10.50	—4.76	21.00	—4.76
	2.11	—5.21	5.28	—5.30	10.55	—5.21	21.10	—5.21
	2.12	—5.66	5.30	—5.66	10.60	—5.66	21.20	—5.66
	2.13	—6.10	5.32	—6.02	10.65	—6.10	21.30	—6.10
	2.14	—6.54	5.35	—6.54	10.70	—6.54	21.40	—6.54
	2.15	—6.98	5.38	—7.06	10.75	—6.98	21.50	—6.98
	2.16	—7.41	5.40	—7.41	10.80	—7.41	21.60	—7.41
	2.17	—7.83	5.42	—7.75	10.85	—7.83	21.70	—7.83
	2.18	—8.26	5.45	—8.26	10.90	—8.26	21.80	—8.26
	2.19	—8.68	5.48	—8.78	10.95	—8.68	21.90	—8.68
	2.20	—9.09	5.50	—9.09	11.00	—9.09	22.00	—9.09

CHECK RATE AND OPEN RATE

Rates are expressed in cubic feet an hour

Meter type	*Standard capacity rate, gas*	*Check rate at 20 per cent of standard rate*	*Diameter of check-rate cap in inches*	*Open rate, approximate, for air*
5 A	175	35	0 18	280
10 A	375	75	0 27	600
30 A	875	175	0 43	1400
60 A	1500	300	0 56	2400
150 A	3400	680	0 85	5440
5 B	150	30	0 16	240
10 B	300	60	0 24	480
20 B	450	90	0 30	720
30 B	600	120	0 35	960
60 B	1300	260	0 52	2080
100 B	1800	360	0 62	2880
150 B	3000	600	0 79	4800
200 B	3100	620	0 81	4960
250 B	4500	900	0 97	7200
500 B	7500	1500	1 25	12000
6 C	600	120	0 35	960
11 C	1120	225	0 49	1800
25 C	2500	500	0 73	4000
40 C	4000	800	0 92	6400
60 C	6000	1200	1 12	9600
175 C	17500	3500	1 92	28000

The approximate diameters of the caps are based on the check rate being 20 per cent of the standard rate. Air is used for testing. The pressure at the inlet of the meter is 1.5 inches of water and the thickness of the cap is 0.0625 inch. The approximate open rate is based on the assumption that air is used for testing and the pressure at the inlet to the meter is about 1.5 inches of water.

SPECIFICATIONS OF SPRAGUE GAS METERS

Size	Dimensions: Center of Connections	Height	Front to Back	Width	Proving Head	Teeth in Top Bracket	Cu. Ft. Per Rev.	Capacities* (W.C. Diff.) ½″	1″	1.7″ or 1 oz.	Aluminum Weight Lbs.	Cast Iron Weight Lbs.	Size Pipe Connections Inches
No. 1A	6″	13½″	7⅞″	9 7/16″	2 ft.	15	.133	175	241	315	13	29½	¾, 1 & 1¼
No. 2	7 3/16″	15½″	8¾″	10¾″	5 ft.	24	.208	305	435	575	20	45	1 & 1¼
No. 3	6 25/32″	17 3/16″	9 11/16″	12¼″	5 ft.	17	.294	400	540	654	25	52½	1½ & 1½
No. 4	10″	22½″	13⅞″	15⅞″	5 ft.	**16	.625	600	900	1250	55	132	1¼ & 1½
No. 5A	10⅞″	26 5/16″	15½″	18″	20 ft.	17	1.177	1000	1490	1850	78	190	2

*5″ inlet pressure, 0.60 Sp. G. **Double worm.

SPECIFICATIONS FOR 1500 SPRAGUE REGULATOR

Description	Size of Connections	Size of Orifice	Weight	Max. Cu. Ft. Cap. per Hr.
Lever Type Regulator with Streamlined Valve Cap, 6⅝″ Diaphragm, Dead Weight and Spring Loaded, Seal and No Seal, Pounds to Inches and Pounds to Pounds Types Available.	¾″ to 2″ pipe	⅛″ to ½″	14 lb.	Up to 3000

The trend of new type regulators is to better their performance and increase the capacity in order to reduce the many sizes now prevalent.

SPRAGUE COMBINATION METER AND REGULATOR

The combination meter and regulator consists of a standard meter with the regulator built as an integral part of the top. The unit has the following advantages in the field and in the shop: (1) The regulator and meter can be installed in an area no greater than that occupied by a conventional low-pressure setup, (2) a considerable amount of space can be saved in storage areas in the shop and on transportation units, (3) fewer fittings are necessary resulting in a more rigid installation and (4) the reduction in the quantity of fittings eliminates some of the sources of leaks, and the added rigidity reduces to some extent the possibility of leakage.

In group installations the combination provides individual pressure control for each consumer regardless of the length of the house line or whether the connected load is large or small. In the advent of trouble call it is only necessary to shut off the service to the customer involved. The other consumers are in no way affected as would be the case in a conventional regulator and header set-up. The benefits of this feature are twofold: (1) individual pressure control, and (2) localization of trouble.

With the combination unit the meter number serves as an identification for both meter and regulator. Inspection and servicing of the regulator becomes part of the meter repair at the periodic changes. This can be accomplished at a cost only slightly higher than an ordinary meter repair.

CAST IRON AND ALUMINUM CASES

Meter cases are now made in both cast iron and aluminum. The cast iron case has been standard for many years. With the event of new types of alloys and requests for light-weight meters having all the advantages of cast iron, the aluminum alloy meter has been brought forth to meet the necessary specifications. The advantages of the aluminum case meter are, freedom from rust, requires no paint, light to handle, no fire hazard, and all parts being interchangeable with older models.

MEASUREMENT—AT HIGH PRESSURE

Gas meters always measure the gas at line pressure. It is not always practicable to reduce the pressure and measure the gas at low pressure. In many instances it would be necessary to compress the gas again to transmit it to the point of consumption.

Meters for high pressure service have the same measuring mechanism as those employed for low pressure. The only difference is in the strength of the case.

If the line pressure does not remain constant, it is necessary to equip the meter with a recording volume and pressure gauge in order to arrive at the correct base or selling pressure. The correct volume is computed from the guage chart and a pressure table.

If the line pressure remains constant, a pressure and volume gauge is not necessary. The correct pressure factor may be taken from the table and applied directly to the meter reading.

The generally accepted average atmospheric pressure is 14.4 pounds. Gauge pressure is the difference between the absolute pressure and the atmospheric pressure, viz., the absolute pressure equals the atmospheric pressure plus guage pressure. Absolute pressure must be used in all gas calculations involving the gas laws.

The method of converting volume measured at high pressure to volume at a base or selling pressure is as follows:

Meter Reading	215,512 cu. ft.
Atmospheric pressure	14.4 pounds per sq. in.
Base pressure	4 ounces
Gauge pressure	45 pounds per sq. in.

In the table under "Base pressure 4 ounces" observe the constant for 45 pounds gauge pressure. It is found to be 4.055. Multiply the meter reading by this constant to obtain the volume measured at the selling pressure, or 4.055 x 215,512 = 873,901 cu. ft.

If the pressure varies, it is necessary to employ a recording volume and pressure gauge. An average pressure for the volume measured is calculated from the gauge chart. This average pressure is then interpolated in table of pressure factors and the calculations from this point are identical to those employed for a constant pressure.

Sprague Meter Company.

CRITICAL FLOW ORIFICE PROVERS

The critical flow orifice prover may be used for testing positive displacement meters at a pressure of 15 pounds gauge or more by passing gas or air through the meter and the orifice, and discharging it into the atmosphere.

If the proof of the meter does not change with changes in pressure (it should not) the time required for a full circle reading of the proving hand of the index will be the same for any particular orifice and any kind of gas, regardless of variations in pressure.

To test a meter under working pressure conditions, the prover is attached to a connection close to the meter outlet.

The orifice of proper size for testing the meter should be selected from a table furnished by the manufacturer showing the approximate time required for the passage of one cubic foot of air. A .500-inch orifice should be used for testing a meter at a rate of 4000 cu. ft. (index reading) an hour. A .250-inch orifice may be used for the low test rate.

On account of the small size of the orifice used, it is not practicable to calculate the standard air time by the measurement of the diameter of the orifice. It is always determined by test and is stamped on the outlet side of the disc by the manufacturer.

The "gas time" for a test with any orifice depends upon the size of the orifice, the ratio of specific heats of the gas, the temperature of the specific gravity.

Tables to simplify the calculations in connection with the testing of meters with critical flow orifice provers are furnished by the manufacturer.

See American Meter Company Bulletin E-8.

PRESSURE FACTORS FOR HIGH PRESSURE MEASUREMENT

Guage Pressure Pounds	Base Pressure, Pounds Absolute 14.65 (4 oz.)	14.9 (8 oz.)	15.025 (10 oz.)	16.4 (2 lb.)	Guage Pressure Pounds	Base Pressure, Pounds Absolute 14.65 (4 oz.)	14.9 (8 oz.)	15.025 (10 oz.)	16.4 (2 lb.)
0	0.983	0.966	0.958	0.878	38	3.577	3.517	3.488	3.195
1	1.051	1.034	1.025	0.939	39	3.645	3.584	3.554	3.256
2	1.119	1.101	1.092	1.000	40	3.713	3.651	3.621	3.317
3	1.188	1.168	1.158	1.061	41	3.782	3.718	3.687	3.378
4	1.256	1.235	1.225	1.122	42	3.849	3.785	3.754	3.439
5	1.324	1.302	1.291	1.183	43	3.918	3.852	3.820	3.500
6	1.392	1.369	1.358	1.244	44	3.986	3.919	3.887	3.561
7	1.461	1.436	1.424	1.305	45	4.055	3.987	3.953	3.622
8	1.529	1.503	1.491	1.366	46	4.123	4.054	4.020	3.683
9	1.597	1.570	1.557	1.427	47	4.191	4.121	4.087	3.744
10	1.666	1.638	1.624	1.488	48	4.259	4.188	4.153	3.805
11	1.734	1.705	1.691	1.549	49	4.328	4.255	4.220	3.866
12	1.802	1.772	1.757	1.610	50	4.396	4.322	4.286	3.927
13	1.870	1.839	1.824	1.671	51	4.464	4.389	4.353	3.988
14	1.939	1.906	1.890	1.732	52	4.532	4.456	4.419	4.049
15	2.007	1.973	1.957	1.793	53	4.601	4.523	4.486	4.110
16	2.075	2.040	2.023	1.854	54	4.669	4.591	4.552	4.171
17	2.143	2.107	2.090	1.915	55	4.737	4.658	4.619	4.232
18	2.212	2.174	2.156	1.976	56	4.805	4.725	4.686	4.293
19	2.280	2.242	2.223	2.037	57	4.874	4.792	4.752	4.354
20	2.348	2.309	2.290	2.098	58	4.942	4.859	4.819	4.415
21	2.416	2.376	2.356	2.159	59	5.010	4.926	4.885	4.476
22	2.485	2.443	2.423	2.220	60	5.078	4.993	4.952	4.537
23	2.553	2.510	2.489	2.280	61	5.147	5.060	5.018	4.598
24	2.621	2.577	2.556	2.341	62	5.215	5.128	5.085	4.659
25	2.689	2.644	2.622	2.402	63	5.283	5.195	5.151	4.720
26	2.758	2.711	2.689	2.463	64	5.352	5.262	5.218	4.780
27	2.826	2.779	2.755	2.524	65	5.420	5.329	5.285	4.841
28	2.894	2.846	2.822	2.585	66	5.488	5.396	5.351	4.902
29	2.962	2.913	2.889	2.646	67	5.556	5.463	5.418	4.963
30	3.031	2.980	2.955	2.707	68	5.625	5.530	5.484	5.024
31	3.099	3.047	3.022	2.768	69	5.693	5.597	5.551	5.085
32	3.167	3.114	3.088	2.829	70	5.761	5.664	5.617	5.146
33	3.235	3.181	3.155	2.890	71	5.829	5.732	5.684	5.207
34	3.304	3.248	3.221	2.951	72	5.898	5.799	5.750	5.268
35	3.372	3.315	3.288	3.012	73	5.966	5.866	5.817	5.329
36	3.440	3.383	3.354	3.073	74	6.034	5.933	5.884	5.390
37	3.509	3.450	3.421	3.134	75	6.102	6.000	5.950	5.451

METHOD FOR DETERMINING REGULATOR CAPACITIES

A study of the various equations now in use for computing regulator capacities reveals that the following seem to be the most practical:

(1) Where the flow is below critical velocity (regulator outlet absolute pressure being more than one half of the regulator inlet absolute pressure): $Q = K\sqrt{h\,p_o}$

(2) Where the flow is above critical velocity (regulator outlet absolute pressure being less than one half of regulator inlet absolute pressure): $Q = \frac{1}{2}\,KP_1$

Where,

Q = M Cu. Ft. per hour of .65 Sp. Gr. Gas at a base press. of 14.73 Lbs. per Sq. In. absolute

h = Drop in pressure across regulator in Lbs. per Sq. In.

P_o = Absolute outlet pressure in Lbs. per Sq. In.

P_1 = Absolute inlet pressure in Lbs. per Sq. In.

K = Constant, depending on regulator valve size and characteristics

For convenience, these equations are transposed as follows:

$$Q = K \times \text{Flow Factor}$$

Graphic Charts Figures 1, 2, 3, & 4 have been prepared whereby flow factors may be read directly, depending upon the regulator inlet and outlet pressures.

The "Flow Factor" (shown on bottom scale) is equal to $\sqrt{hp_o}$, for conditions outlined under equation (1); and is equal to $\frac{1}{2}\,P_1$, for conditions outlined under equation (2). These flow factors when multiplied by factor "K" (in table) equal the recommended maximum regulator capacity.

In attempting to determine "K" factors for practical use for the different regulators in common use, it is necessary to make several compromises and assumptions which are briefly stated as follows:

(1) It is interpreted that the maximum capacity of a regulator is that quantity of gas which a regulator will deliver at a given pressure drop between its inlet and outlet flanges; that is, the regulator body is considered the unit rather than only the regulator valves or any part of the setting.

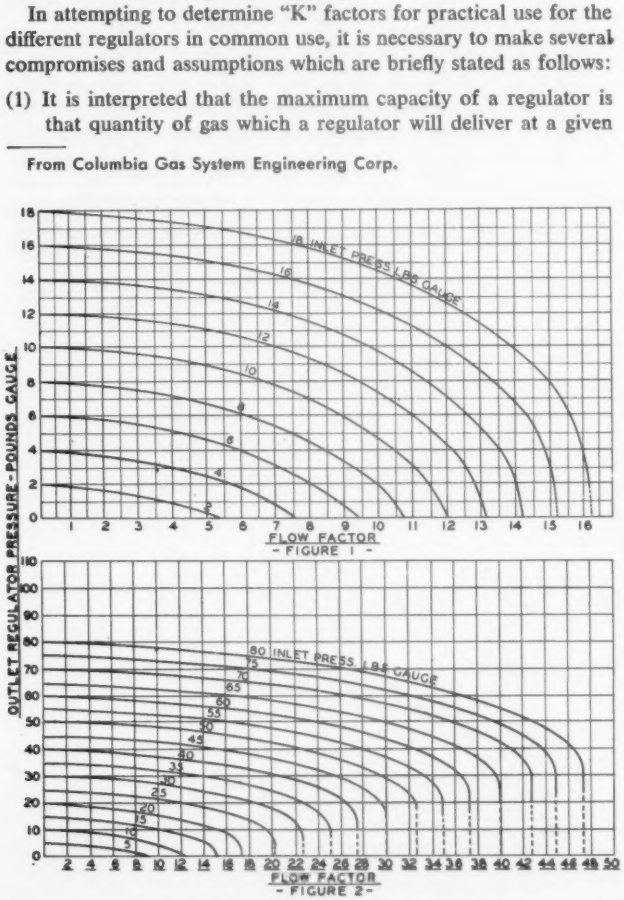
(2) In developing practical "K" factors for the different regulators, it is known that some regulators have greater valve opening areas than the area of the regulator outlet pipe opening. In such cases, the capacity should be reduced to an amount equivalent to a valve opening area equal to approximately 60 per cent of the regulator outlet pipe opening cross sectional area.

(3) These capacity data are based entirely on the capacity of the regulator main body and do not take into account variations in outlet pressure resulting from other causes, such as friction, lack of operative power, etc., which are rather common in the older type of regulator.

The table sets forth practical "average values" for K, which are believed to be accurate and safe for the purpose intended. In most instances they are as accurate as many of the other variables involved, such as the estimated inlet and outlet pressures, etc. Where more accurate values of "K" are available, such as those furnished by regulator manufacturers, obtained from special tests, etc., they may be substituted for those in the table and inserted in the blank spaces provided.

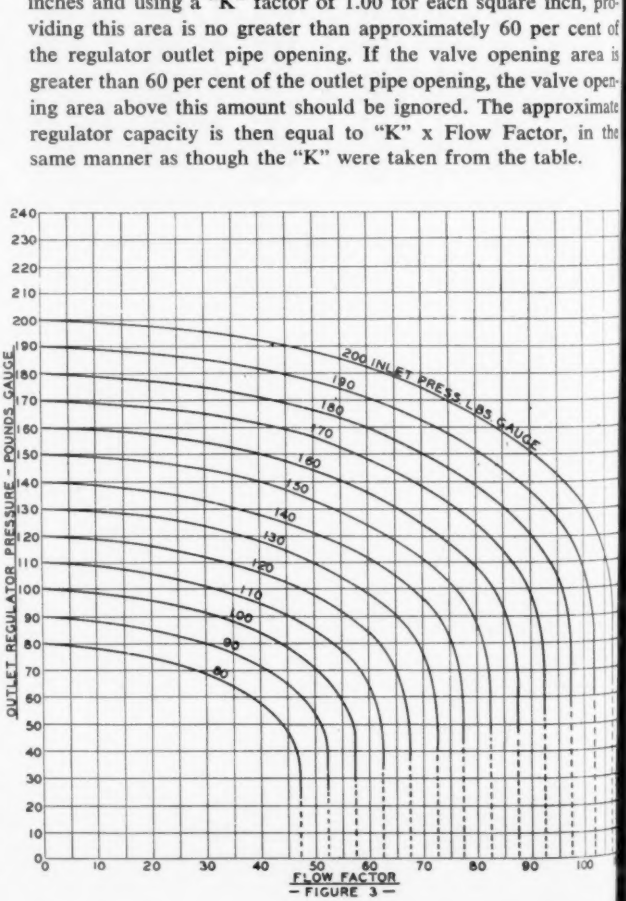
There may be instances where special regulators are in use and it is desired to obtain their approximate capacity. This may be done by determining the valve opening area in terms of square inches and using a "K" factor of 1.00 for each square inch, providing this area is no greater than approximately 60 per cent of the regulator outlet pipe opening. If the valve opening area is greater than 60 per cent of the outlet pipe opening, the valve opening area above this amount should be ignored. The approximate regulator capacity is then equal to "K" x Flow Factor, in the same manner as though the "K" were taken from the table.

From Columbia Gas System Engineering Corp.

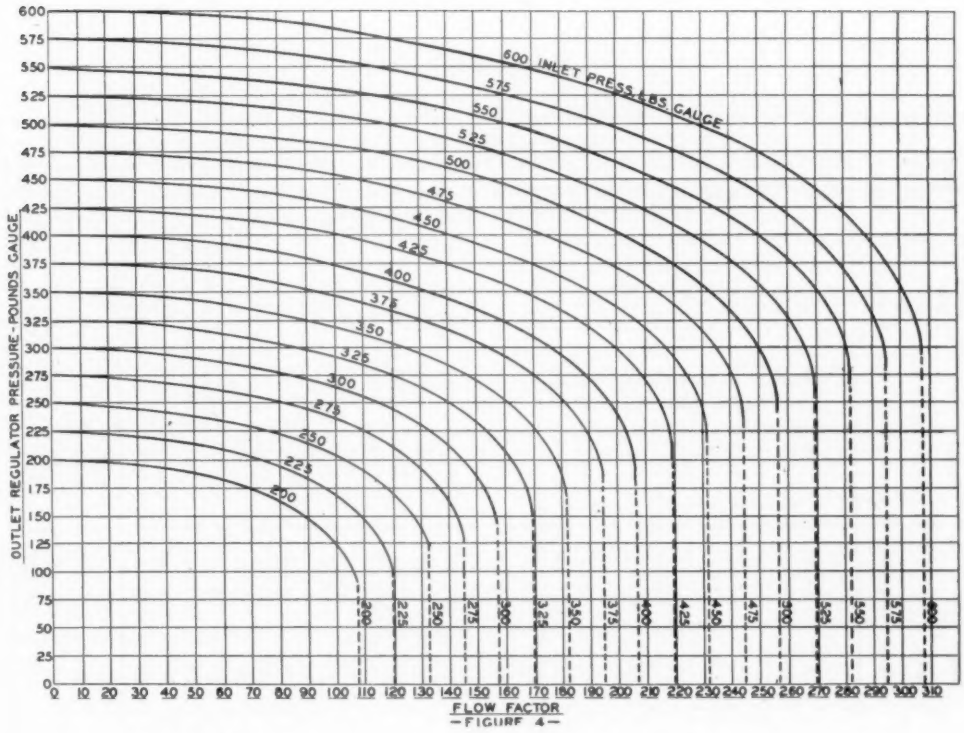


- FIGURE 1 -

- FIGURE 2 -



- FIGURE 3 -



—FIGURE 4—

To determine Maximum Capacity of Regulator:

(1) Locate outlet pressure on left margin of graph
(2) Trace horizontally to estimated minimum inlet pressure
(3) Trace vertically down and read "Flow Factor" on bottom scale
(4) Maximum hourly capacity = Flow Factor x "K" factor

Example:

Assume—A 6" Regulator, 25 Lb. Outlet Gauge Pressure, and an estimated minimum inlet Gauge Pressure of 40 Lb.

Then —From graph (Figure 2) Flow Factor = 24.5, and from table "K" Factor = 16.5
Maximum Regulator Capacity = 24.5 x 16.5 or 400 M. Cubic Feet per Hour

To determine size regulator required when the quantity and pressure conditions are known:

Example:

Assume—A maximum hourly rate of flow 100 M. Cu. Ft. per Hour, an Outlet Pressure of 100 Lb., and an estimated minimum inlet Pressure of 250 Lb.

Then —From Graph (Figure 4), Flow Factor = 133, therefore "K" Factor required = 100 ÷ 133 or .75
It will be noted from table shown that a 2" regulator having 1" balanced valves will have ample capacity.

Practical K Factors For Use In Determining Regulator Capacities

Size Regulator	K Factors "Average Values"
2" (¾" Balanced Valves)	.43
2" (1" " ")	1.4
2" (Std. " ")	1.9
3" (" " ")	4.2
4" (" " ")	7.5
6" (" " ")	16.5
8" (" " ")	27.5
10" (" " ")	42.0
12" (" " ")	61.0

DIMENSION DATA ON TELESCOPIC WET SEAL GAS HOLDERS

Capacity Thousand Cubic Feet	Number of Lifts	Tank Dimensions Diam.	Tank Dimensions Height	Number of Columns	Pressure Inflated with Air — LIFTS 1st	2nd	3rd	4th	All	Usual Conn. Diam.	FOUNDATION Diameter	Excavation Cu.Yds.	Concrete Cu.Yds.	Water Load per Sq. Ft. on Bottom	Water To Fill Tank Gallons
5	One	25'-0"	12'-6"	4	4.8"				4.8"	6"	27'-6"	69	54	767	45,000
10	One	32'-0"	15'-6"	4	5.1"				5.1"	6"	34'-6"	84	69	955	91,700
15	One	37'-0"	17'-0"	4	4.5"				4.5"	10"	39'-6"	96	81	1048	134,700
20	One	40'-6"	18'-6"	5	4.6"				4.6"	10"	43'-0"	105	90	1142	175,900
25	One	42'-0"	21'-3"	5	4.8"				4.8"	10"	44'-6"	109	94	1315	207,400
30	One	44'-6"	22'-6"	6	4.8"				4.8"	12"	47'-0"	134	108	1395	258,800
40	One	50'-6"	23'-0"	6	5.1"				5.1"	12"	53'-0"	164	138	1422	340,700
50	One	55'-6"	23'-8"	6	4.8"				4.8"	12"	58'-0"	168	142	1465	424,300
60	One	59'-6"	24'-6"	6	4.6"				4.6"	12"	62'-0"	189	155	1533	505,000
75	One	64'-0"	26'-3"	8	4.6"				4.6"	12"	66'-6"	198	172	1628	625,700
100	One	71'-3"	28'-0"	8	4.4"				4.4"	12"	73'-9"	226	200	1735	828,200
125	One	79'-3"	28'-0"	9	4.5"				4.5"	12"	81'-9"	259	233	1735	840,700
75	Two	50'-6"	23'-0"	9	5.6"				9.7"	12"	53'-0"	165	139	1422	340,700
100	Two	57'-5"	23'-10"	9	5.4"				9.1"	12"	59'-11"	190	164	1478	457,000
125	Two	62'-0"	25'-6"	9	5.9"				10.0"	12"	64'-6"	206	180	1582	570,200
150	Two	66'-6"	26'-0"	9	5.6"				9.4"	16"	69'-0"	248	208	1610	669,000
200	Two	73'-2"	28'-3"	9	5.2"				8.8"	16"	75'-8"	278	238	1752	882,000
250	Two	79'-8"	29'-9"	10	5.5"				9.1"	16"	82'-2"	308	268	1848	1,101,100
300	Two	84'-3"	31'-4"	10	5.5"				9.1"	16"	86'-9"	332	292	1945	1,294,900
400	Two	93'-3"	34'-0"	10	6.1"				9.9"	24"	95'-9"	403	348	2110	1,729,300
500	Two	102'-0"	35'-2"	12	5.4"				8.9"	24"	104'-6"	455	400	2185	2,134,300
300	Three	75'-0"	28'-3"	9	5.0"	8.3"			11.2"	16"	78'-0"	316	276	1752	925,300
400	Three	80'-0"	32'-4"	10	5.5"	9.1"			12.3"	24"	83'-0"	364	309	2010	1,206,100
500	Three	93'-9"	28'-10"	10	5.2"	8.2"			10.8"	24"	96'-9"	440	385	1788	1,475,600
600	Three	95'-4½"	34'-0"	10	6.1"	9.8"			13.0"	24"	98'-4½"	450	395	2110	1,805,000
750	Three	104'-7"	35'-0"	12	6.0"	9.6"			12.6"	24"	107'-7"	504	449	2170	2,240,600
1,000	Three	118'-6"	35'-9"	14	5.9"	9.5"			12.7"	24"	121'-6"	605	550	2220	2,928,700
1,500	Three	142'-5"	36'-3"	16	5.5"	8.7"			11.4"	30"	145'-5"	857	754	2250	4,293,700
1,000	Four	105'-0"	35'-0"	12	7.2"	11.1"	14.7"		17.9"	30"	108'-0"	605	502	2185	2,245,000
1,500	Four	136'-6"	30'-10"	14	5.5"	8.5"	11.2"		13.6"	30"	139'-6"	843	740	1915	3,350,000
2,000	Four	145'-5"	35'-8"	16	5.9"	8.6"	11.1"		13.0"	36"	148'-5"	976	863	2215	4,411,300
3,000	Four	175'-0"	36'-3"	18	5.5"	8.4"	11.0"		13.3"	36"	178'-0"	1253	1140	2250	6,477,000
5,000	Five	204'-4"	35'-9"	22	5.2"	7.5"	9.6"	11.7"	13.5"	36"	207'-4"	1613	1500	2220	8,709,700
6,000	Five	210'-2"	40'-6"	22	5.8"	8.1"	10.4"	12.5"	14.3"	42"	213'-2"	1739	1590	2520	10,477,300
8,000	Five	240'-9"	40'-4"	24	6.0"	8.3"	10.5"	12.7"	14.5"	42"	243'-9"	2129	1980	2500	13,670,800
10,000	Five	276'-6"	38'-2"	28	5.1"	7.0"	8.7"	10.4"	14.7"	42"	279'-6"	2639	2490	2375	17,031,300

NATIONAL API
PLAIN END PIPE FOR OIL, GAS, AND GASOLINE LINES

Ends Finished for Specified Couplers or Welded Joints

This table is intended for the determination of sizes and thicknesses for long lines. It includes all sizes listed in American Petroleum Institute Line Pipe Specification No. 5-L, tenth edition.

"R" indicates regular sizes and weights, which can be furnished most readily; sizes and weights indicated by "L" are not regularly available for immediate shipment. It may not always be possible to consider the manufacture of these items in small quantities.

The permissible variation in weight for all the pipe is in accordance with the API Specification. The weights indicated by the letter "R" will not vary more than 3½ per cent under or 10 per cent over that specified and the lighter weights (indicated by the letter "L") will not vary more than 5 per cent under or 10 per cent over that specified.

The working pressures with safety factors are given for Grade A seamless and for Grade B seamless. To obtain the working pressure for other factors of safety, multiply the pressure shown by the given safety factor and divide by the safety factor desired.

Barlow's Formula was used in calculating the listed working, test, and bursting pressures:

$$P = 2f\,\frac{t}{D}$$

D = outside diameter of pipe—inches;
t = nominal thickness of wall—inches;
P = internal pressure—pounds per square inch;
f = fiber stress—pounds per square inch.

When plain end pipe is ordered beveled for welding, caulking, or other purposes, it is understood that the angle specified is to be measured from a line drawn perpendicular to the axis of the pipe, which means that a greater amount of material is removed with a 60-degree angle than with a 30-degree angle. Unless otherwise specified, pipe ordered for welding will be beveled 30 degrees.

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Size: outside diameter	Weight per foot plain ends	Wall thickness		Net tons per mile	[1] Ultimate bursting pressures		Test pressures		[1] Working pressures					
									Grade A seamless			Grade B seamless		
									Factor of safety					
		Fraction	Decimal of inch		Grade A seamless	Grade B seamless	Grade A seamless	Grade B seamless	3	4	5	3	4	5
Ins.	Lbs.				PSI		PSI		PSI			PSI		
3½	4.51 L	⅛	.125	11.906	3570	4290	1300	1500	1190	890	710	1430	1070	860
3½	5.58 L	5/32	.156	14.731	4460	5360	1600	1900	1490	1120	890	1790	1340	1070
3½	6.63 R	3/16	.188	17.503	5360	6430	1900	2200	1790	1340	1070	2140	1610	1290
3½	7.58 R	..	.216	20.011	6170	7410	2200	2500	2060	1540	1230	2470	1850	1480
3½	8.68 R	¼	.250	22.915	7140	8570	2500	2500	2380	1780	1430	2860	2140	1710
3½	9.67 R	9/32	.281	25.529	8030	9630	2500	2500	2680	2010	1610	3210	2410	1930
3½	10.25 R	..	.300	27.060	8570	10290	2500	2500	2860	2140	1710	3430	2570	2060
4	5.17 L	⅛	.125	13.649	3120	3750	1100	1300	1040	780	630	1250	940	750
4	6.41 L	5/32	.156	16.922	3900	4690	1400	1600	1300	980	780	1560	1170	940
4	7.63 L	3/16	.188	20.143	4690	5630	1700	2000	1560	1170	940	1880	1410	1130
4	9.11 L	..	.226	24.050	5650	6780	2000	2400	1880	1410	1130	2260	1700	1360
4	10.01 L	¼	.250	26.426	6250	7500	2200	2500	2080	1560	1250	2500	1880	1500
4	11.17 L	9/32	.281	29.489	7030	8440	2500	2500	2340	1760	1410	2810	2110	1690
4	12.51 L	..	.318	33.028	7950	9540	2500	2500	2650	1990	1590	3180	2390	1910
4½	5.84 L	⅛	.125	15.418	2780	3330	1000	1200	930	700	560	1110	830	670
4½	7.25 L	5/32	.156	19.140	3470	4160	1200	1500	1160	870	690	1390	1040	830
4½	8.64 R	3/16	.188	22.810	4170	5000	1500	1800	1390	1040	830	1670	1250	1000
4½	10.00 R	7/32	.219	26.400	4870	5840	1700	2000	1620	1220	970	1940	1460	1170
4½	10.79 R	..	.237	28.486	5270	6320	1900	2200	1760	1320	1050	2110	1580	1280
4½	11.35 R	¼	.250	29.984	5560	6670	2000	2300	1850	1390	1110	2220	1670	1330
4½	12.67 R	9/32	.281	33.449	6250	7500	2200	2500	2080	1560	1250	2500	1880	1500
4½	13.98 R	5/16	.312	36.907	6940	8330	2500	2500	2310	1740	1390	2780	2080	1670
4½	14.98 R	..	.337	39.547	7490	8990	2500	2500	2500	1870	1500	3000	2250	1800
5 9/16	9.02 L	5/32	.156	23.813	2810	3370	1000	1200	940	700	560	1120	840	670
5 9/16	10.76 L	3/16	.188	28.406	3370	4040	1200	1400	1120	840	670	1350	1010	810
5 9/16	12.49 L	7/32	.219	32.974	3930	4720	1400	1700	1310	980	790	1570	1180	940
5 9/16	14.02 L	..	.258	38.597	4640	5570	1700	1900	1550	1160	930	1860	1390	1110
5 9/16	15.87 L	9/32	.281	41.897	5060	6060	1800	2100	1680	1260	1010	2020	1520	1210
5 9/16	17.82 L	5/16	.312	46.253	5620	6740	2000	2400	1870	1400	1120	2250	1690	1350
5 9/16	19.16 L	11/32	.344	50.582	6180	7410	2200	2500	2060	1540	1240	2470	1850	1480
5 9/16	20.78 L	⅜	.375	54.859	6740	8090	2400	2500	2250	1680	1350	2700	2020	1620
6⅝	12.89 R	3/16	.188	34.030	2830	3400	1000	1200	940	710	570	1130	850	680
6⅝	14.87 R	7/32	.219	39.521	3300	3960	1200	1400	1100	830	660	1320	990	790
6⅝	17.02 R	¼	.250	44.933	3770	4530	1400	1600	1280	940	750	1510	1130	910
6⅝	18.97 R	..	.280	50.081	4230	5070	1500	1800	1410	1060	850	1690	1270	1010
6⅝	21.07 R	5/16	.312	55.625	4720	5660	1700	2000	1570	1180	940	1890	1420	1130

[1] Values indicated are non-API.

Size: outside diameter	Weight per foot plain ends	Wall thickness		Net tons per mile	[1] Ultimate bursting pressures		Test pressures		[1] Working pressures					
		Fraction	Decimal of inch		Grade A seamless	Grade B seamless	Grade A seamless	Grade B seamless	Grade A seamless			Grade B seamless		
									Factor of safety					
									3	4	5	3	4	5
Ins.	Lbs.				PSI		PSI		PSI			PSI		
6⅝	23.06 R	11/32	.344	60.878	5190	6230	1900	2200	1730	1300	1040	2080	1560	1250
6⅝	25.03 R	3/8	.375	66.079	5660	6790	2000	2400	1890	1420	1130	2260	1700	1360
6⅝	28.57 R	..	.432	75.425	6520	7820	2300	2500	2170	1630	1300	2610	1960	1560
8⅝	16.90 R	3/16	.188	44.616	2170	2610	800	900	720	540	430	870	650	520
8⅝	19.64 R	7/32	.219	51.850	2540	3040	900	1100	850	630	510	1010	760	610
8⅝	22.36 R	1/4	.250	59.030	2900	3480	1000	1200	970	720	580	1160	870	700
8⅝	24.70 R	..	.277	65.208	3210	3850	1200	1300	1070	800	640	1280	960	770
8⅝	27.74 R	5/16	.312	73.234	3620	4350	1300	1500	1210	910	720	1450	1090	870
8⅝	28.55 R	..	.322	75.372	3730	4480	1300	1600	1240	930	750	1490	1120	900
8⅝	30.40 R	11/32	.344	80.256	3990	4780	1400	1700	1330	1000	800	1590	1200	960
8⅝	33.04 R	3/8	.375	87.226	4350	5220	1600	1800	1450	1090	870	1740	1300	1040
8⅝	38.26 R	7/16	.438	101.006	5070	6090	1800	2100	1690	1270	1010	2030	1520	1220
8⅝	43.39 R	1/2	.500	114.550	5800	6960	2100	2400	1930	1450	1160	2320	1740	1390
10¾	21.15 L	3/16	.188	55.836	1750	2100	650	750	580	440	350	700	520	420
10¾	24.60 R	7/32	.219	64.944	2030	2440	750	850	680	510	410	810	610	490
10¾	28.04 R	1/4	.250	74.026	2330	2790	850	1000	780	580	470	930	700	560
10¾	31.20 R	..	.279	82.368	2600	3110	1000	1200	870	650	520	1040	780	620
10¾	34.24 R	..	.307	90.394	2860	3430	1000	1200	950	710	570	1140	860	690
10¾	38.20 R	11/32	.344	100.848	3200	3840	1100	1300	1070	800	640	1280	960	770
10¾	40.48 R	..	.365	106.867	3400	4070	1200	1400	1130	850	680	1360	1020	810
10¾	48.19 R	7/16	.438	127.222	4070	4880	1500	1700	1360	1020	810	1630	1220	980
10¾	54.74 R	1/2	.500	144.514	4650	5580	1700	2000	1550	1160	930	1860	1400	1120
12¾	29.28 L	7/32	.219	77.299	1720	2060	600	700	570	430	340	690	510	410
12¾	33.38 R	1/4	.250	88.123	1960	2350	700	800	650	490	390	780	580	470
12¾	37.45 R	9/32	.281	98.868	2210	2650	800	950	740	550	440	880	660	530
12¾	41.51 R	5/16	.312	109.586	2450	2940	900	1000	820	610	490	980	740	590
12¾	43.77 R	..	.330	115.553	2580	3110	1000	1200	860	650	520	1040	780	620
12¾	45.55 R	11/32	.344	120.252	2700	3240	1000	1200	900	670	540	1080	810	650
12¾	49.56 R	3/8	.375	130.838	2940	3530	1100	1200	980	740	590	1180	880	710
12¾	57.53 R	7/16	.438	151.879	3430	4120	1200	1400	1140	860	690	1370	1030	820
12¾	65.42 R	1/2	.500	172.709	3920	4710	1400	1600	1310	980	780	1570	1180	940
14	36.71 L	1/4	.250	96.914	1790	2140	650	750	600	450	360	710	540	430
14	41.21 L	9/32	.281	108.794	2010	2410	700	850	670	500	400	800	600	480
14	45.68 R	5/16	.312	120.595	2230	2680	800	950	740	560	450	890	670	540
14	50.14 R	11/32	.344	132.370	2460	2950	900	1000	820	610	490	980	740	590
14	54.57 R	3/8	.375	144.065	2680	3210	950	1100	890	670	540	1070	800	640
14	63.37 R	7/16	.438	167.297	3130	3750	1100	1300	1040	780	630	1250	940	750
14	72.09 R	1/2	.500	190.318	3570	4290	1300	1500	1190	890	710	1430	1070	860
16	42.05 L	1/4	.250	111.012	1560	1880	550	650	520	390	310	630	470	380
16	47.22 L	9/32	.281	124.661	1760	2110	650	750	590	440	350	700	530	420
16	52.36 R	5/16	.312	138.230	1950	2340	700	800	650	490	390	780	590	470
16	57.48 R	11/32	.344	151.747	2150	2580	750	900	720	540	430	860	640	520
16	62.58 R	3/8	.375	165.211	2340	2810	850	1000	780	590	470	940	700	560
16	72.72 R	7/16	.438	191.981	2730	3280	1000	1100	910	680	550	1090	820	660
16	82.77 R	1/2	.500	218.513	3130	3750	1100	1300	1040	780	630	1250	940	740
18	47.39 L	1/4	.250	125.110	1390	1670	500	600	460	350	280	560	420	330
18	53.22 L	9/32	.281	140.501	1560	1880	550	650	520	390	310	630	470	380
18	59.03 R	5/16	.312	155.839	1740	2080	600	750	580	430	350	690	520	420
18	64.82 R	11/32	.344	171.125	1910	2290	700	800	640	480	380	760	570	460
18	70.59 R	3/8	.375	186.358	2080	2500	750	900	690	520	420	830	630	500
18	82.06 R	7/16	.438	216.638	2430	2920	900	1000	810	610	490	970	730	580
18	93.45 R	1/2	.500	246.708	2780	3330	1000	1200	930	690	560	1110	830	670
20	52.73 L	1/4	.250	139.207	1250	1500	450	500	420	310	250	500	380	300
20	59.23 L	9/32	.281	156.367	1410	1690	500	600	470	350	280	560	420	340
20	65.71 R	5/16	.312	173.474	1560	1880	550	650	520	390	310	630	470	380
20	72.16 R	11/32	.344	190.502	1720	2060	600	700	570	430	340	690	520	410
20	78.60 R	3/8	.375	207.504	1880	2250	700	800	630	470	380	750	560	450
20	91.41 R	7/16	.438	241.322	2190	2630	800	900	730	550	440	880	660	530
20	104.13 R	1/2	.500	274.903	2500	3000	900	1000	830	630	500	1000	750	600
22	72.38 L	5/16	.312	191.083	1420	1700	500	600	470	360	280	570	430	340
22	79.51 L	11/32	.344	209.906	1560	1880	550	650	520	390	310	630	470	380
22	86.61 L	3/8	.375	228.650	1700	2050	600	700	570	430	340	680	510	410
22	100.75 L	7/16	.438	265.980	1990	2390	700	850	660	500	400	800	600	480
22	114.81 L	1/2	.500	303.096	2270	2730	800	950	760	570	450	910	680	550
24	79.06 L	5/16	.312	208.718	1300	1560	450	550	430	330	260	520	390	310
24	86.85 L	11/32	.344	229.284	1430	1720	500	600	480	360	290	570	430	340
24	94.62 L	3/8	.375	249.797	1560	1880	550	650	520	390	310	630	470	380
24	110.10 L	7/16	.438	290.664	1820	2190	650	750	610	460	360	730	550	440
24	125.49 L	1/2	.500	331.294	2080	2500	750	850	690	520	420	830	620	500
[2]26	85.73 L	5/16	.312	226.33	1200	1440	450	500	400	300	240	480	360	290
[2]26	102.63 L	3/8	.375	270.94	1440	1730	500	600	480	360	290	580	430	350
[2]26	119.44 L	7/16	.438	315.32	1680	2020	600	700	560	420	340	670	500	400
[2]26	136.17 L	1/2	.500	359.49	1920	2310	700	800	640	480	380	780	580	460

[1] Values indicated are non-API.
[2] This is a non-API size.

TAPPING CAST IRON MAINS FOR SERVICE RUNS

Size of Main	3"	4"	6"	8"	10"	12"	16"	20"	24"	30"
Maximum Size of Tap	¾"	1"	1½"	2"	2½"	2½"	3"	4'	4"	4"

The maximum size of tap that should be made in cast iron gas mains of different sizes is shown in the accompanying table.

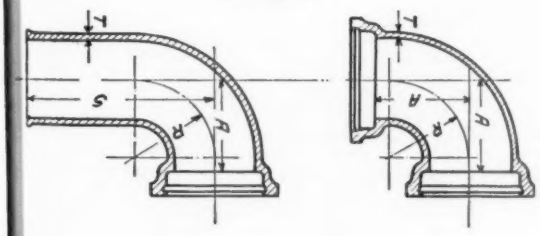
When not to be used for a service, a 1¼" hole may be tapped in a 4" main and a 1" hole in a 3" main.

CAST IRON PIPE OTHER THAN PIT CAST

The following table gives tentative metal thickness and weights per foot of barrel, based on 18,000–40,000 metal and centrifugal cast pipe. The metal thickness shown is recommended for laying condition "B"—under 5'-0" cover, flat bottom trench without blocks and tamped backfill

	Class 50		*Class 100*		*Class 150*		*Class 200*		*Class 250*	
Size	*Thickness*	*Wt. Per Ft. of Barrel*	*Thickness*	*Wt. Per Ft. of Barrel*	*Thickness*	*Wt. Per Ft. of Barrel*	*Thickness*	*Wt. Per Ft. of Barrel*	*Thickness*	*Wt. Per Ft. of Barrel*
3	30	10.29	30	10 29	30	10 29	30	10 29	30	10.29
4	32	14 05	32	14 05	32	14 05	32	14 05	32	14.05
6	35	22 47	35	22 47	35	22 47	35	22 47	35	22 47
8	38	32 29	38	32 29	38	32 29	38	32.29	38	32 29
10	41	42.96	41	42 96	41	42 96	41	42 96	44	45 97
12	44	55 04	44	55 04	44	55 04	48	59 85	52	64 64
14	47	68 30	51	73 91	51	73 91	55	79 50	59	85 05
16	54	89 24	54	89 24	54	89 24	58	95 62	63	103 55
18	58	107 56	58	107 56	58	107 56	63	116 52	68	125 44
20	62	127 50	62	127 50	62	127 50	67	137 45	72	147 36
24	63	155 43	68	167 43	73	179 38	79	193 66	79	193 66
30	79	239 66	79	239 66	85	257 36				
36	87	316 30	87	316 30	94	341 09				
42	97	411 02	97	411 02	1 05	444 09				
48	1 06	513 68	1 06	513 68	1 14	551 55				

BENDS



SLEEVES, CAPS AND PLUGS

	Solid Sleeves		Caps	Plugs
Nominal Diameter Inches	Over-all Length Inches	Weight Pounds	Weight Pounds	Weight Pounds
3"	12	38	..	..
4"	12	47	25	9
6"	12	65	37	16
8"	15	100	52	24
10"	15	122	65	34
12"	15	160	95	50
16"	18	269	151	83

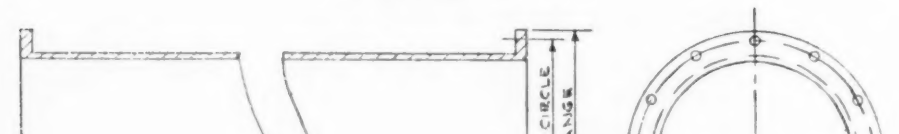
	Quarter Bends			Eighth Bends			Sixteenth Bends		
Nominal Diameter Inches	Dimensions, Inches A	S	Weight Lbs.	Dimensions, Inches A	S	Weight Lbs.	Dimensions, Inches A	S	Weight Lbs.
4	4.50	26	68	3.16	23	63	2.69	20.25	58
6	6.25	26	100	4.23	23	97	3.53	20.75	91
8	8.00	26	149	5.31	23	138	4.38	21.25	130
10	9.75	26	198	6.39	23	183	5.22	22.00	175
12	11.25	27	278	7.22	24	253	5.81	22.50	239

The above weights are for bends with one bell and one spigot. The weights of quarter and eighth bends with two average about 7% less and of sixteenth bends 5% less.

Specifications for Bends, Sleeves, Caps and Plugs are those of the American Gas Association

STANDARD FLANGED CAST IRON PIPE

With 25 Lb. Cast Iron Flanges



Dimensions in Inches

Nominal Diameter Inches	*Actual Outside Diameter Inches*	*T 10 Lb. Pressure Class*	*T'*[2, 3]	*Diameter of Flange*	*Diameter of Bolt Circle*	*Size of Bolts*	*Length of Bolts*	*Number of Bolts*[1]	*Approximate Weight in Pounds*		
									One Flange[5]	*Flanged Pipe Per Foot*[6]	*12'-0" Length*[4, 7]
4	4.80	40	3/4	9	7 1/2	5/8	2 1/4	8			
6	6.90	43	3/4	11	9 1/2	5/8	2 1/4	8			
8	9.05	46	7/8	13 1/2	11 3/4	5/8	2 1/4	8			
10	11.10	50	7/8	16	14 1/4	5/8	2 1/2	12			
12	13.20	54	1	19	17	5/8	2 3/4	12			
16	17.40	58	1 1/8	23 1/2	21 1/4	3/4	3 1/4	16			
20	21.60	66	1 1/4	27 1/2	25	3/4	3 1/2	20			
24	25.80	74	1 3/8	32	29 1/2	3/4	3 3/4	20			
30	31.74	87	1 1/2	38 3/4	36	7/8	4 1/4	28			
36	37.96	97	1 5/8	46	42 3/4	7/8	5	32			
42	44.20	1.07	1 3/4	53	49 1/2	1	5 1/4	36			
48	50.50	1.18	2	59 1/2	56	1	5 1/2	44			
54	56.66	1.35	2 1/4	66 1/4	62 3/4	1	5 3/4	44			
60	62.80	1.39	2 1/4	73	69 1/4	1 1/8	6	52			
72	75.34	1.62	2 1/2	86 1/2	82 1/2	1 1/8	6 1/4	60			

NOTE: T— for heavier standards see Table No. 2.—Std. thicknesses and Weights of Pit Cast Pipe.

[1]NOTE: Drilling templates are in multiples of four, so that fittings may be made to face in any quarter, and bolt holes straddle the center line. Bolt holes are drilled 1/8 inch larger in diameter than the nominal diameter of the bolt.

[2]NOTE: All 25 lb. cast iron standard flanges have plain faces.

[3]NOTE: Screwed companion flanges "should not be thinner than the 125 lb. American Standard' thickness on sizes 24 in. and smaller. Other types of flanges may have thicknesses as given in the table above."

[4]NOTE: Lengths may be made up with one or both flanges screwed on provided full face is machined after flanges are made up.

[5]NOTE: Weight of flange includes only metal beyond O.D. of pipe.

[6]NOTE: Weight per foot includes flanges.

[7]NOTE: Actual length = 11'-11 13/16"

STANDARD 125 LB. CAST IRON FLANGES

Dimensions in Inches

Nominal Pipe Size	*Diameter of Flange*	*Thickness of Flange (Min.)*[2]	*Diameter of Bolt Circle*	*Number of Bolts*[1]	*Diameter of Bolts*	*Length of Bolts*
4	9	13/16	7 1/2	8	5/8	3
6	11	1	9 1/2	8	3/4	3 1/4
8	13 1/2	1 1/8	11 3/4	8	3/4	3 1/2
10	16	1 3/16	14 1/4	12	7/8	3 3/4
12	19	1 1/4	17	12	7/8	3 3/4
16	23 1/2	1 7/16	21 1/4	16	1	4 1/2
20	27 1/2	1 11/16	25	20	1 1/8	5
24	32	1 7/8	29 1/2	20	1 1/4	5 1/2
30	38 3/4	2 1/8	36	28	1 1/4	6 1/4
36	46	2 3/8	42 3/4	32	1 1/2	7
42	53	2 5/8	49 1/2	36	1 1/2	7 1/2
48	59 1/2	2 3/4	56	44	1 1/2	7 3/4
54	66 1/4	3	62 3/4	44	1 3/4	8 1/2
60	73	3 1/8	69 1/4	52	1 3/4	8 3/4
72	86 1/2	3 1/2	82 1/2	60	1 3/4	9 1/2

NOTE: 125 lb. flanges are recommended for under-ground work.

[1]NOTE: Drilling templates are in multiples of four, so that fittings may be made to face in any quarter, and bolt holes straddle the center line. For bolts smaller than 1 3/4 in. the bolt holes shall be drilled 1/8 in. larger in diameter than the nominal diameter of the bolt. Holes for bolts 1 3/4 in. and larger shall be drilled 1/4 in. larger than nominal diameter of bolts.

[2]NOTE: All of these cast iron standard flanges have plain faces.

NOTE: The 125 lb. and the 25 lb. flanges have the same diameters, bolt circles, and number of bolts. The 25 lb. flange has a reduction in the thickness of flanges and the bolt diameters. This gives interchangeability between the two type of flanges.

WEIGHTS, DIMENSIONS AND SPECIFICATIONS OF MECHANICAL JOINT CAST IRON PIPE, FITTINGS AND ACCESSORIES

The following are the weights, dimensions and descriptions of mechanical joint cast iron pipe, fittings and accessories as specified by the Cast Iron Pipe Research Association. All items here shown are standardized and interchangeable regardless of which member, or members, of the association they are obtained from. All fittings are made to dimensions, as shown in the tables of high quality cast iron and are rigidly inspected and tested. They are furnished with sockets at all openings unless otherwise specified. Socket dimensions of pipe and fittings are the same.

Joint surfaces are protected against corrosion during storage and shipment. Fittings are furnished uncoated and unlined unless otherwise specified.

General Specifications. Pipe shall be cast iron produced centrifugally in sand lined or metal molds, horizontally in green sand molds or by the pit cast method. Each pipe shall be provided with a mechanical joint socket on one end and the other end shall be plain. Fittings shall be provided with sockets at all openings unless specifically ordered otherwise.

Pipe shall be tested in a suitable hydraulic press to the pressure indicated in the appropriate pipe specification.

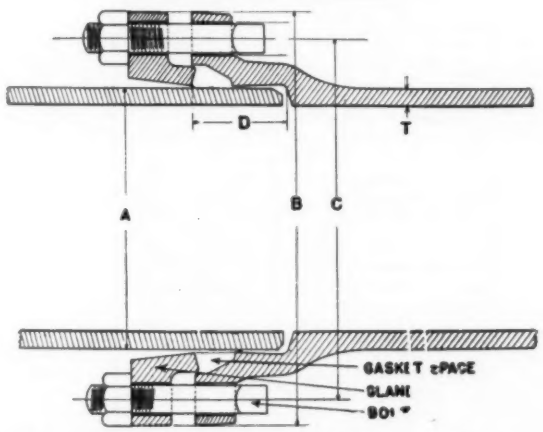
Pipe and fittings shall be furnished to dimensions as tabulated. All sockets and plain ends shall be checked with ring and plug gages.

Pipe and fittings shall be furnished uncoated and unlined unless otherwise specified. If coatings are required, they shall meet specifications agreed upon by the purchaser and seller.

All joint surfaces shall be protected by suitable means at the foundry against corrosion during storage and shipment.

(Continued on page 112)

MECHANICAL JOINT CAST IRON PIPE



DIMENSIONS IN INCHES												
SIZE	A	B	C	D	T	T	T	T**	BOLTS			Weight of Gland, Bolts and Gaskets, lbs.
					A.G.A.	Class 150 WWP-421	Class 250 WWP-421	Class 22 A.S.A.	No.	Size	Lg'th	
3	3.96	7.50	6.19	2.50	.39	.33*	.36*	.32	4	⅝	3	6
4	4.80	8.88	7.50	2.50	.40	.34	.38	.35	4	¾	3½	11
6	6.90	10.88	9.50	2.50	.43	.37	.43	.38	6	¾	3½	16
8	9.05	13.13	11.75	2.50	.45	.42	.50	.41	6	¾	4	22
10	11.10	15.50	14.00	2.50	.49	.47	.57	.44	8	¾	4	28
12	13.20	17.75	16.25	2.50	.54	.50	.62	.48	8	¾	4	35
14	15.30	20.25	18.75	3.50	.57	.55	–	.51	10	¾	4	47
16	17.40	22.50	21.00	3.50	.62	.60	–	.54	12	¾	4½	60
18	19.50	24.75	23.25	3.50	.64	.65	–	.58	12	¾	4½	73
20	21.60	27.00	25.50	3.50	.68	.68	–	.62	14	¾	4½	83
24	25.80	31.50	30.00	3.50	.76	.76	–	.68	16	¾	5	112
30	32.00	38.75	36.50	4.00	.85	.89*	–	.79	20	1	5½	207
36	38.30	45.50	43.25	4.00	.95	1.01*	–	.87	24	1	5½	276
42	44.50	52.50	50.00	4.00	1.07	1.11*	–	.97	28	1¼	6	377
48	50.80	59.00	56.50	4.00	1.26	1.22*	–	1.06	32	1¼	6	431

* Thickness of 3", 30", 36", 42", 48" computed by Fairchild Formula.

** Thickness computed by A.S.A. Method of Design. Pipe in steps of 8% increase in thickness over Class 22 can be furnished.

WEIGHTS OF MECHANICAL JOINT PIPE
12 FOOT LENGTHS

Size	O. D.	A. G. A. Spec.			Federal Spec. WWP-421						Proposed A. S. A. Spec.		
					Class 150			Class 250			Class 22		
		T.	Wt. /ft. Incl. Socket	Wt. /12 ft. Length	T.	Wt. /ft. Incl. Socket	Wt. /12 ft. Length	T.	Wt. /ft. Incl. Socket	Wt. /12 ft. Length	T.	Wt. /ft. Incl. Socket	Wt. /12 ft. Length
3	3.96	.39	14.6	175	.33	12.6	150	.36	13.6	165	.32	12.3	150
4	4.80	.40	18.6	225	.34	16.2	195	.38	17.8	215	.35	16.6	200
6	6.90	.43	29.1	350	.37	25.5	305	.43	29.1	350	.38	26.1	315
8	9.05	.45	40.5	485	.42	38.0	460	.50	44.4	530	.41	37.2	445
10	11.10	.49	54.2	650	.47	52.3	630	.57	62.1	745	.44	49.3	590
12	13.20	.54	71.2	855	.50	66.4	795	.62	80.7	970	.48	63.9	765
14	15.30	.57	88.8	1065	.55	86.0	1030				.51	80.4	965
16	17.40	.62	109.9	1320	.60	106.7	1280				.54	97.1	1165
18	19.50	.64	127.4	1530	.65	129.5	1555				.58	117.0	1405
20	21.60	.68	150.6	1805	.68	150.6	1805				.62	138.7	1665
24	25.80	.76	201.3	2415	.76	201.3	2415				.68	182.1	2185
30	32.00	.85	282.4	3390	.89	294.4	3535				.79	264.6	3175
36	38.30	.95	378.9	4550	1.01	400.3	4805				.87	350.4	4205
42	44.50	1.07	495.9	5950	1.11	512.5	6150				.97	454.3	5450
48	50.80	1.26	661.8	7940	1.22	642.9	7715				1.06	566.8	6790

16 FOOT LENGTHS

Size	O. D.	A. G. A. Spec.			Federal Spec. WWP-421						Proposed A. S. A. Spec.		
					Class 150			Class 250			Class 22		
		T.	Wt. /ft. Incl. Socket	Wt. /16 ft. Length	T.	Wt. /ft. Incl. Socket	Wt. /16 ft. Length	T.	Wt. /ft. Incl. Socket	Wt. /16 ft. Length	T.	Wt. /ft. Incl. Socket	Wt. /16 ft. Length
3	3.96	.39	14.4	230	.33	12.4	200	.36	13.4	215	.32	12.1	195
4	4.80	.40	18.2	290	.34	15.9	255	.38	17.5	270	.35	16.3	260
6	6.90	.43	28.6	460	.37	25.1	400	.43	28.7	460	.38	25.7	410
8	9.05	.45	39.8	640	.42	37.4	600	.50	43.8	700	.41	36.6	585
10	11.10	.49	53.4	855	.47	51.5	825	.57	61.3	980	.44	48.5	775
12	13.20	.54	70.1	1120	.50	65.3	1045	.62	79.6	1290	.48	62.9	1005
14	15.30	.57	87.2	1400	.55	84.4	1350				.51	78.8	1260
16	17.40	.62	107.9	1725	.60	104.7	1675				.54	95.1	1520
18	19.50	.64	125.4	2005	.65	127.2	2035				.58	114.7	1835
20	21.60	.68	147.8	2365	.68	147.8	2360				.62	136.0	2175
24	25.80	.76	197.6	3160	.76	197.5	3160				.68	178.4	2855
30	32.00	.85	276.7	4430	.89	288.7	4620				.79	258.9	4145
36	38.30	.95	371.2	5940	1.01	392.5	6280				.87	342.6	5480
42	44.50	1.07	485.6	7770	1.11	502.4	8040				.97	444.2	7105
48	50.80	1.26	649.3	10390	1.22	630.4	10085				1.06	553.3	8850

18 FOOT LENGTHS

Size	O. D.	A. G. A. Spec.			Federal Spec. WWP-421						Proposed A. S. A. Spec.		
					Class 150			Class 250			Class 22		
		T	Wt./ft. Incl. Socket	Wt./18 ft. Length	T	Wt./ft. Incl. Socket	Wt./18 ft. Length	T	Wt./ft. Incl. Socket	Wt./18 ft. Length	T	Wt./ft. Incl. Socket	Wt./18 ft. Length
3	3.96	.39	14.3	255	.33	12.3	220	.36	13.3	240	.32	12.0	215
4	4.80	.40	18.1	330	.34	15.8	285	.38	17.4	315	.35	16.2	290
6	6.90	.43	28.5	515	.37	24.9	450	.43	28.5	515	.38	25.5	460
8	9.05	.45	39.6	715	.42	37.2	670	.50	43.6	785	.41	36.4	655
10	11.10	.49	53.1	955	.47	51.2	920	.57	61.0	1100	.44	48.2	870
12	13.20	.54	69.8	1255	.50	65.0	1170	.62	79.3	1430	.48	62.6	1125
14	15.30	.57	86.6	1560	.55	83.8	1510				.51	78.2	1410
16	17.40	.62	107.2	1930	.60	104.1	1875				.54	94.5	1700
18	19.50	.64	124.6	2240	.65	126.4	2280				.58	113.9	2050
20	21.60	.68	146.8	2640	.68	146.8	2640				.62	134.9	2430
24	25.80	.76	196.4	3535	.76	196.3	3535				.68	177.3	3190

High strength *Cast Iron Tee Head Bolts and Hex Nuts* shall be furnished in sufficient quantities to provide for each socket opening on pipe and fittings. These bolts shall have a minimum tensile strength of 50,000 pounds per square inch.

Cast Iron Glands shall be furnished in sufficient quantities to provide for each socket opening on pipe and fittings. These glands shall be made of high strength Cast Iron.

Gaskets shall be furnished in sufficient quantities to provide for each socket opening on pipe or fittings. The type of gasket shall be as stipulated in sales contract.

The gaskets furnished for the standardized mechanical joint cast iron pipe under the above specifications are produced by long established manufacturers who are recognized specialists in this field, and are made to accurate dimensions under rigid controls and inspection. Generally plain rubber gaskets are furnished and in sufficient quantities to provide for each socket opening on pipe and fittings. Metal tipped, duck tipped, Thiokol tipped and other special types of gaskets can be supplied when specified by the purchaser.

The glands are made of special high quality cast iron under rigid metallurgical controls and inspections.

Bolts furnished with the standardized mechanical joint are made of high strength cast iron and have a minimum tensile strength of 50,000 pounds per square inch. They possess the inherent corrosion resistance of cast iron and will therefore play their full part in living up to the long life records of the pipe itself. Other types of bolts for unusual requirements are furnished to meet purchasers' specifications.

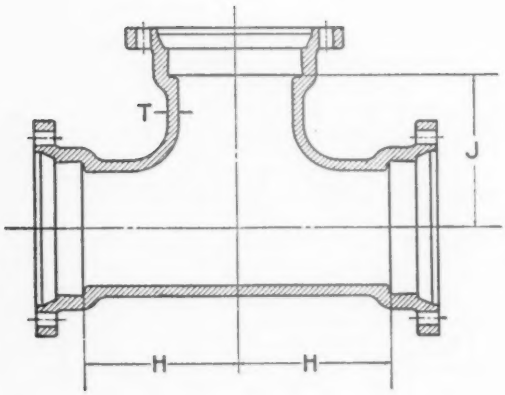
Glands and bolts are furnished in sufficient quantities to provide for each socket opening on pipe and fittings.

FITTINGS OTHER THAN BENDS, TEES AND CROSSES FOR MECHANICAL JOINT CAST IRON PIPE

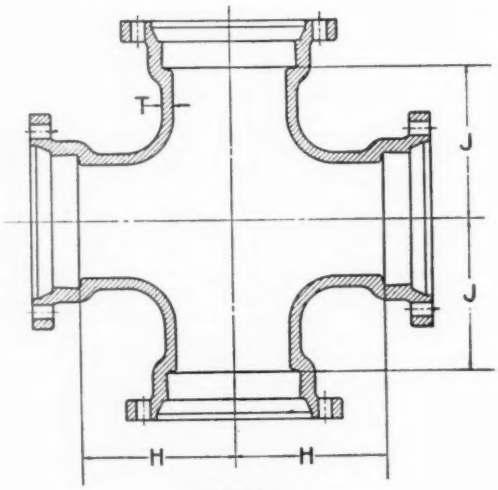
Reducers—Concentric
—Eccentric
Sleeves —Solid
—Split—Can be furnished with boss and tap for service connection
—Transition—Furnished with one end designed for standard steel outside diameter pipe and the other to fit mechanical joint cast iron pipe.
Gland
Split Gland
Plug
Cap
Connecting Piece—Bell (Mech. Joint) and Flange (125 lb. standard)
" " —Spigot and Flange (125 lb. standard)
" " —Bell (Mech. Joint) and Spigot
" " —Bell (Mech. Joint) and Bell (No. 1 for Cement or Head Joint)
" " —2 Bells (Mech. Joint)
Offsets
Drip Pots

All weights are approximate and do not include joint accessories.
22½° and 11¼° bends are also available.
Dimensions in inches, weights in pounds.
Weight of pipe per length rounded off to nearest 5 pounds.
Weights per foot per length include the weight of the socket but do not include the weights of glands, bolts and gaskets.
Lengths available—12 ft. lengths, sizes 3" to 48"
16 ft. lengths, sizes 3" to 48"
16½ ft. lengths, sizes 3" to 30"
18 ft. lengths, sizes 3" to 24"
20 ft. lengths, sizes 12" to 30"

CAST IRON TEES AND CROSSES



TEE

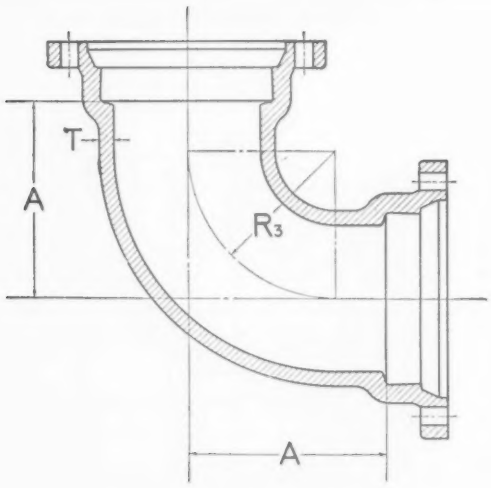


CROSS

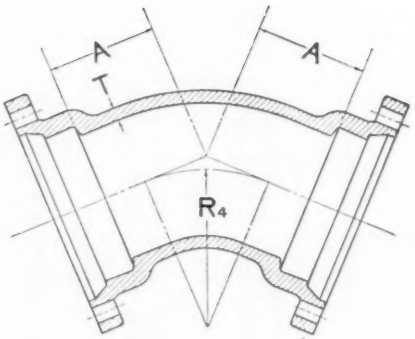
TABLE OF DIMENSIONS										
Nominal Diam.		Outside Diam.		T		H	J	Apx. Weight		Max. Working Pressure, lbs.
Run	Branch	Run	Branch	Run	Branch			TEE	CROSS	
3	3	3.96	3.96	.48	.48	5.5	5.5	53	69	250
4	3	5.00	3.96	.52	.48	6.5	6.5	73	90	250
4	4	5.00	5.00	.52	.52	6.5	6.5	80	104	250
6	3	7.10	3.96	.55	.48	8.0	8.0	109	125	250
6	4	7.10	5.00	.55	.52	8.0	8.0	116	140	250
6	6	7.10	7.10	.55	.55	8.0	8.0	126	161	250
8	4	9.30	5.00	.60	.52	9.0	9.0	163	187	250
8	6	9.30	7.10	.60	.55	9.0	9.0	173	207	250
8	8	9.30	9.30	.60	.60	9.0	9.0	187	234	250
10	4	11.40	5.00	.68	.52	11.0	11.0	237	262	250
10	6	11.40	7.10	.68	.55	11.0	11.0	247	283	250
10	8	11.40	9.30	.68	.60	11.0	11.0	262	312	250
10	10	11.64	11.64	.80	.80	11.0	11.0	308	379	250
12	4	13.50	5.00	.75	.52	12.0	12.0	314	339	250
12	6	13.50	7.10	.75	.55	12.0	12.0	325	360	250
12	8	13.50	9.30	.75	.60	12.0	12.0	339	388	250
12	10	13.74	11.64	.87	.80	12.0	12.0	391	461	250
12	12	13.74	13.74	.87	.87	12.0	12.0	412	502	250
14	6	15.30	7.10	.66	.48	14.0	14.0	417	455	150
14	8	15.30	9.05	.66	.51	14.0	14.0	432	485	150
14	10	15.30	11.10	.66	.57	14.0	14.0	449	519	150
14	12	15.65	13.50	.82	.75	14.0	14.0	528	620	150
14	14	15.65	15.65	.82	.82	14.0	14.0	568	701	150
16	6	17.40	7.10	.70	.48	15.0	15.0	519	557	150
16	8	17.40	9.05	.70	.51	15.0	15.0	534	586	150
16	10	17.40	11.10	.70	.57	15.0	15.0	549	617	150
16	12	17.40	13.20	.70	.62	15.0	15.0	571	660	150
16	14	17.80	15.65	.89	.82	15.0	15.0	693	822	150
16	16	17.80	17.80	.89	.89	15.0	15.0	726	887	150

TABLE OF DIMENSIONS

Nominal Diam.		Outside Diam.		T		H	J	Weight		Max. Working Pressure, lbs.
Run	Branch	Run	Branch	Run	Branch			TEE	CROSS	
18	6	19.50	7.10	.75	.48	13.0	15.5	569	605	150
18	8	19.50	9.05	.75	.51	13.0	15.5	582	632	150
18	10	19.50	11.10	.75	.57	13.0	15.5	598	663	150
18	12	19.50	13.20	.75	.62	13.0	15.5	616	700	150
18	14	19.50	15.30	.75	.66	16.5	16.5	735	857	150
18	16	19.92	17.80	.96	.89	16.5	16.5	888	1052	150
18	18	19.92	19.92	.96	.96	16.5	16.5	924	1122	150
20	6	21.60	7.10	.80	.48	14.0	17.0	687	724	150
20	8	21.60	9.05	.80	.51	14.0	17.0	701	752	150
20	10	21.60	11.10	.80	.57	14.0	17.0	717	784	150
20	12	21.60	13.20	.80	.62	14.0	17.0	736	822	150
20	14	21.60	15.30	.80	.66	14.0	17.0	765	882	150
20	16	21.60	17.40	.80	.70	18.0	18.0	911	1064	150
20	18	22.06	19.92	1.03	.96	18.0	18.0	1107	1308	150
20	20	22.06	22.06	1.03	1.03	18.0	18.0	1143	1379	150
24	6	25.80	7.10	.89	.48	15.0	19.0	931	968	150
24	8	25.80	9.05	.89	.51	15.0	19.0	944	994	150
24	10	25.80	11.10	.89	.57	15.0	19.0	960	1026	150
24	12	25.80	13.20	.89	.62	15.0	19.0	978	1062	150
24	14	25.80	15.30	.89	.66	15	19	1007	1121	150
24	16	25.80	17.40	.89	.70	15	19	1033	1171	150
24	18	25.80	19.50	.89	.75	22	22	1349	1550	150
24	20	26.32	22.06	1.16	1.03	22	22	1661	1921	150
24	24	26.32	26.32	1.16	1.16	22	22	1751	2103	150
30	6	32.00	7.10	1.03	.48	18	23	1586	1625	150
30	8	32.00	9.05	1.03	.51	18	23	1601	1654	150
30	10	32.00	11.10	1.03	.57	18	23	1617	1686	150
30	12	32.00	13.20	1.03	.62	18	23	1636	1723	150
30	14	32.00	15.30	1.03	.66	18	23	1665	1782	150
30	16	32.00	17.40	1.03	.70	18	23	1691	1834	150
30	18	32.00	19.50	1.03	.75	18	23	1720	1892	150
30	20	32.00	21.60	1.03	.80	18	23	1747	1947	150
30	24	32.74	26.32	1.37	1.16	25	25	2699	3030	150
30	30	32.74	32.74	1.37	1.37	25	25	2908	3446	150
36	8	38.30	9.05	1.15	.51	20	26	2269	2320	150
36	10	38.30	11.10	1.15	.57	20	26	2284	2351	150
36	12	38.30	13.20	1.15	.62	20	26	2303	2387	150
36	14	38.20	15.30	1.15	.66	20	26	2331	2444	150
36	16	38.30	17.40	1.15	.70	20	26	2355	2491	150
36	18	38.30	19.50	1.15	.75	20	26	2382	2546	150
36	20	38.30	21.60	1.15	.80	20	26	2408	2598	150
36	24	38.30	25.80	1.15	.89	20	26	2469	2720	150
36	30	39.16	32.74	1.58	1.37	28	28	4054	4570	150
36	36	39.16	39.16	1.58	1.58	28	28	4244	4950	150
42	12	44.50	13.20	1.28	.62	23	30	3228	3317	150
42	14	44.50	15.30	1.28	.66	23	30	3256	3373	150
42	16	44.50	17.40	1.28	.70	23	30	3281	3423	150
42	18	44.50	19.50	1.28	.75	23	30	3308	3477	150
42	20	44.50	21.60	1.28	.80	23	30	3335	3531	150
42	24	44.50	25.80	1.28	.89	23	30	3395	3651	150
42	30	44.50	32.00	1.28	1.03	31	31	4314	4765	150
42	36	45.58	39.16	1.78	1.58	31	31	5684	6359	150
42	42	45.58	45.58	1.78	1.78	31	31	5887	6767	150
48	12	50.80	13.20	1.42	.62	26	34	4350	4443	150
48	14	50.80	15.30	1.42	.66	26	34	4379	4499	150
48	16	50.80	17.40	1.42	.70	26	34	4404	4550	150
48	18	50.80	19.50	1.42	.75	26	34	4432	4605	150
48	20	50.80	21.60	1.42	.80	26	34	4459	4659	150
48	24	50.80	25.80	1.42	.89	26	34	4519	4780	150
48	30	50.80	32.00	1.42	1.03	26	34	4688	5118	150
48	36	50.80	38.30	1.42	1.15	34	34	5757	6340	150
48	42	51.98	45.58	1.96	1.78	34	34	7567	8411	150
48	48	51.98	51.98	1.96	1.96	34	34	7757	8788	150



90°



45°

TABLE OF DIMENSIONS

Nominal Diam.	Outside Diam.	T	90° Bend		45° Bend		Max. Working Pressure	R_3	R_4
			A	Approx. Weight	A	Approx. Weight			
3	3.96	.48	5.5	35	3.0	30	250	4.00	3.62
4	5.00	.52	6.5	54	4.0	47	250	4.50	4.81
6	7.10	.55	8.0	84	5.0	73	250	6.00	7.25
8	9.30	.60	9.0	127	5.5	108	250	7.00	8.44
10	11.40	.68	11.0	188	6.5	155	250	9.00	10.88
12	13.50	.75	12.0	256	7.5	215	250	10.00	13.25
14	15.30	.66	14.0	339	7.5	272	150	11.50	12.06
16	17.40	.70	15.0	429	8.0	342	150	12.50	13.28
18	19.50	.75	16.5	542	8.5	422	150	14.00	14.50
20	21.60	.80	18.0	666	9.5	517	150	15.50	16.87
24	25.80	.89	22.0	997	11.0	734	150	18.50	18.13
30	32.00	1.03	36.0	2086	15.0	1362	150	36.00	27.75
36	38.30	1.15	48.0	3454	18.0	2029	150	48.00	35.00
42	44.50	1.28	48.0	4469	21.0	2876	150	48.00	42.25
48	50.80	1.42	54.0	6138	24.0	3909	150	54.00	49.50

"CARBOSEAL" ANTI-LEAK

"Carboseal"* anti-leak is a product made by Carbide and Carbon Chemicals Corp. and widely sold for correcting leakage in bell and spigot joints in cast iron systems distributing dry gas.

Gases inherently dry are:

(a) Natural gas.

(b) Hydrocarbon gases such as propane and butane with or without air carburetion.

(c) Manufactured gas passed through transmission lines at high or intermediate pressure and distributed at low pressure through district governors in the same system.

(d) Manufactured gas which has been compressed for transmission at high pressures to neighboring communities for low pressure distribution.

(e) Mixed manufactured and natural gas.

The problem presented by increased joint leakage attendant upon the substitution of dry gas for wet was recognized many years ago and various means were adopted for correcting this condition:

(a) A method reported to be entirely satisfactory by many companies consists of applying a leak clamp at each joint after properly preparing the face of the bell to receive the clamp. This involves expensive excavation and repaving costs in addition to the cost of the clamp itself.

(b) Rehydration. Dry gases stored in water-sealed holders pick up some water and the send-out may be partially saturated particularly in the summer months. Any benefit secured from this water vapor is probably restricted to mains within a limited radius.

(c) Oil fogging. Oil fogging has been adopted alone or in conjunction with rehydration in many systems. The principal claims for oil fogging are that it postpones drying out of the packing in bell and spigot joints following a changeover, prevents the formation of, and lays, dust in the system and postpones drying out of leather meter diaphragms where the original dressing oils have been leached out by condensable hydrocarbons present in "wet" gas formerly distributed.

"Carboseal" weighs approximately 9.2 lb. per gal. The liquid has solvent properties for tar and gum and penetrates the packing material readily, swelling it approximately 45 per cent by volume. It will climb to a vertical height of 24 in. in a joint.

The liquid has a high boiling point and a very low vapor pressure. Tendency to evaporate is negligible because of these properties and because the liquid is absorbed intimately into the jute fibres where the swelling action is produced. This material has been variously estimated by users to have a permanency of at least ten to twelve years. The components of the material are inherently non-corrosive. Inhibitors have been added to provide corrosion protection.

The most widely used method of applying the antileak is to insert it at the high points in the system, recovering for re-use the excess material which flows by gravity into the drips. Filling stations at the high points can be established by drilling and tapping the main. Theoretically, the amount required to treat a mile of 3-in. main or its equivalent is 265 lb. This quantity will saturate the packing, fill all the voids, and coat the entire inner surface of pipe which is free from dust and rust deposits. Actual experience over a period of years indicates that due to the presence of such factors as sags and dust in the main, the average total quantity required is 450 lb. per mile of 3-in. main or equivalent. The total cost of treatment including the liquid required, labor and materials, runs from $82 to $600 per mile of 3-in. equivalent with the weighted average in the neighborhood of $300 per mile.

On a project where it is proposed to treat a very old bell and spigot joint cast iron main, one should first excavate and then secure some yarn from old joining material. This yarn should be tested for its capillary attraction qualifications. If found to have lost most of its capillary attraction and does not absorb and carry the "carbosealing" liquid material, the gas joint leaks may not be stopped when the main is treated with Carboseal. On the other hand, should the capillary attraction be good, the leaky gas main joints will probably be stopped upon treatment with this material.

* The word "Carboseal" is a registered trade-mark of Carbide and Carbon Chemicals Corporation.

RESISTANCE OF PIPE FITTINGS TO FLOW EQUIVALENT FEET OF STRAIGHT PIPE

Steam—Air—Gas

Nominal pipe size inches	Actual inside diameter inches	Gate Valve	Long radius ell or one run of standard tee	Medium radius ell or one run of tee reduced in size 25 per cent.	Standard ell or one run of tee reduced in size 50 per cent.	Angle Valve	Close return bend	Tee through side outlet	Globe Valve
Resistance factor for type of fitting		0.25	0.33	0.42	0.67	0.90	1.00	1.33	2.00
½	0.622	0.31	0.41	0.53	0.84	1.1	1.3	1.7	2.5
¾	0.824	0.44	0.57	0.73	1.2	1.6	1.8	2.3	3.5
1	1.049	0.57	0.77	0.98	1.6	2.1	2.3	3.1	4.7
1¼	1.380	0.83	1.1	1.4	2.2	2.9	3.3	4.4	6.5
1½	1.610	0.98	1.3	1.6	2.6	3.5	3.9	5.2	7.8
2	2.067	1.3	1.7	2.2	3.5	4.6	5.2	7.1	10.6
2½	2.469	1.6	2.2	2.8	4.4	5.9	6.6	8.7	13.1
3	3.068	2.1	2.8	3.6	5.7	7.7	8.5	11.4	17.1
4	4.026	3.0	3.9	5.0	7.9	10.7	11.8	15.8	23.7
5	5.047	3.9	5.1	6.5	10.4	13.9	15.5	20.7	31.0
6	6.065	4.8	6.4	8.1	12.9	17.4	19.3	25.6	38.5
8	7.981	6.7	8.9	11.3	17.9	24.1	26.8	35.6	53.8
10	10.020	8.8	11.5	14.7	23.4	31.5	35.0	46.6	70.0
12	12.000	10.9	14.4	18.4	29.3	39.3	43.7	58.1	87.4

Based on Foster's formula $L = 43.7\ r.\ d.^{1.3}$

in which L = equivalent length straight pipe in feet

r = resistance factor

d = diameter of fitting in feet

(A. S. M. E. Trans.)

WELDING—PIPE LINES (OIL AND GAS)

The simplicity, speed and high quality of arc welding has resulted in almost all cross-country pipe lines being completely welded.

Following is a general description of modern practice in the construction of oil and gas lines, using the plain end joint with liner for gas lines, and the plain end joint without liner for oil lines.

Where so called "roll welding" of pipe sections can be done, out in front of the entire construction gang goes the lineup and tacking crew. Aided by a tractor and hoist, they put the pipe lengths on ball-bearing dollies for rolling. The tack welder tacks the adjacent lengths of pipe together usually at four points in the circumference. He joins as many lengths as the nature of the line and the contour of the country will permit. The long tack-welded section is then left on the dollies ready for the firing line welders who follow close behind.

In recent years, the "stove-pipe" method has come into widest use, especially for lines over rough terrain where roll-welding of long sections is difficult. It is also used over fairly smooth or rolling country. Here, all joints (usually plain end without liner) are position-welded like bell-hole joints. One joint at a time is added to the line, making it possible to reduce the size of the crew and amount of equipment, and keep operations bunched together under one supervisor. During alignment and tacking, the joint is usually held in place by a line-up clamp or "grasshopper." After tacking, two bell-hole welders work simultaneously on both sides of the joint, making the complete first bead, each welder coming down from the top.

The wall thickness of the pipe for river crossings is generally 50% to 100% greater than that used in the rest of the line. The pipe is roll-welded and bell-hole welded into a section long enough to cross the river. Each joint is often reinforced by a welded-on sleeve. Special river clamps, four to ten feet long and weighing 1000 to 3000 lbs. each are often bolted to the pipe at intervals, serving as a means of anchoring. The pipe section is then attached by cable to tractors and pulled onto pontoons from which it is guided by stakes into a dredged out ditch in the river bottom. It is usually buried at a minimum depth of eight feet.

The welding speed data in the accompanying tables are based on the average time consumed in making all welds on an average length pipe line from start to finish of the job, including delays, outages and moving time. In other words, it is the average production that can be expected per joint per hour on pipe line construction except where otherwise noted.

AVERAGE SPEEDS FOR PIPE LINE WELDING

Size	*Roll Welding Without Back-Up Ring* — *Average Welds Per Hour*	*Position Welding Without Back-Up Ring* (*After 1st Bead Run By Tackers*) — *Average Welds Per Hour*
6″	6.0	6.5
8″	5.5	5.0
10″	4.0	4.5
12″	3.5	3.75
14″	3.0	**3.0**
16″	2.75	2.50
18″	2.50	2.25
20″	2.25	2.25
22″	2.1	2.0
24″	2.0	2.0
26″	1.5	1.25
30″	1.25	1.0

Note: Roll and Position Welding Without Back-up Ring: For all sizes of pipe use a space of 1/16″ to 1/8″.

POUNDS OF ELECTRODE PER WELD*

Size Pipe	*Pounds*
6″	.75
8″	1.00
10″	1.25
12″	1.50
14″	1.75
16″	2.00
18″	2.25
20″	2.50
22″	2.75
24″	3.00
26″	3.25
30″	4.00

* Based on 1/4″ to 5/16″ wall thickness pipe.

RECOMMENDED SIZES OF ELECTRODE FOR PIPE LINE WELDING

Size	*Roll Welding Without Back-Up Ring* — *Stringer Bead*	*Second Bead*	*Third Bead*	*Position Welding Without Back-Up Ring "Stove Pipe" or "Tie In" Method* — *Stringer Bead*	*Second Bead*	*Third Bead*
4″	5/32″	3/16″	1/4″	....	....	....
6″	5/32″	1/4 ″	1/4″	5/32″	5/32″	3/16″
8″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″
10″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″
12″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″
14″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″
16″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″
18″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″
20″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″
22″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″
24″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″
26″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″
30″	5/32″ or 3/16″	1/4 ″	1/4″ or 5/16″	5/32″	5/32″	3/16″

Position welding with back-up ring: Use 3/16″ rod for all beads on all sizes of pipe.

Note: Use 3/16″ electrode on additional beads when necessary.

The firing line crew, including several welders, completes the welds of the long sections. These operators weld at the top of the pipe while a helper turns the pipe by means of a chain pipe wrench. Thus, all welding is done in a flat, downhand position, and by using large-size electrodes (1/4″, 5/16″ and sometimes 3/8″) and heavy welding current, high welding speeds are obtained. After completion of each bead, a helper cleans all of the slag from the weld. Each completed weld is inspected for any imperfections before the welder proceeds to the next joint. When the section is entirely welded, the pipe is rolled off the dollies and the pipe sections are painted and then joined into a continuous stretch by "bell-hole" welding.

This pipe is placed on timber skids near or over the trench and, in this position, it is "bell-hole" welded. Here, instead of having the pipe rolled beneath the arc, the operator plies the arc around the pipe. For these welds, he uses smaller sized electrodes (5/32″ or 3/16″) with 125 to 200 amperes.

REQUIRED WATER HEATER CAPACITIES

Capacity of Hot Water Equipment Needed to Supply Fixtures in Various Types of Buildings
Gallons Per Maximum Hour

Fixture	Apt. House	Club	Gymnasium	Hospital	Hotel	Indst. Plant	Laundry	Office Bldg.	Public Bath	Private House	School	Y.W.C.A. Y.M.C.A.
Wash Basin (Private)	3	3	3	3	3	3	3	3	3	3	3	3
Wash Basin (Public)	5	8	10	10	10	15	10	15	15	..	15	15
Bath Tub	15	15	30	15	15	30	..	..	45	15	..	30
Dish Washer	15	30	..	30	30	30	..	..	.	15	15	..
Foot Basin	3	3	..	3	3	..	..	..	..	3	..	10
Kitchen Sink	10	20	..	20	20	20	..	..	..	10	10	20
Laundry Tub (Stationary)	25	35	..	35	35	..	45	..	45	25	..	45
Laundry Tub (Revolving)	75	75	..	100	150	..	100	..	100	75	..	100
Pantry Sink	10	20	..	20	20	..	10	..	..	10	20	20
Shower	100	200	300	100	100	300	..	..	300	100	300	200
Slop Sink	20	20	..	20	30	20	..	20	20	15	20	20
Dish Washer				250 Gal	lons per	hour fo	r each	500 peo	ple			
% of Total Water likely be drawn in one hour	20	30	60	40	30	70	80	15	80	30	25	30

Buenger, A. *Journ A.S.H. & V.E.*,

OVERALL EFFICIENCY OF GAS STORAGE WATER HEATERS

$$E_c = \frac{W\,(T_2 - T_1) \times 100}{\frac{W\,(T_2 - T_1)}{E_{ut}} + \left[24 - \left(\frac{W\,(T_2 - T_1)}{R E_{ut}}\right)\right] \times \frac{C S T_R}{100}}$$

Where

E_c = theoretical service or overall efficiency, per cent,

W = total weight of water drawn during 24-hour period, pounds,

E_{ut} = uncorrected thermal efficiency of heater, expressed as a decimal,

T_1 = inlet water temperature, ° F,

T_2 = outlet water temperature, ° F,

$(T_2 - T_1)$ = temperature rise, ° F. (may be assumed as 90° F),

R = input rate of heater, B.t.u. per hour,

C = storage vessel capacity, pounds,

S = standby loss of heater, per cent per hour, and

T_R = average temperature rise of stored water above room temperature, ° F (may be assumed as 90° F.).

Computations of service efficiencies on the basis of thermal efficiency and standby loss test results and in accordance with the above equation which was developed in the course of the work of the Approval Requirements Committee agree reasonably, although not always closely, with service efficiencies determined from actual draw-off tests.

*FLOW IN GALLONS PER MINUTE DELIVERED BY ORDINARY PLUMBING FIXTURES

Fixture	1 Fair Flow	2 Good Flow	3 Excellent Flow
Kitchen Sink Bibbs	2	4	6
Pantry Sink—High Goose Neck Bibbs	2	2	3
Pantry Sink—Large Plain Bibbs	4	6	8
Vegetable Sink Bibbs	2	4	6
Laundry Tray Bibbs	4	6	8
Slop Sink Bibbs	3	4	6
Lavatory Basin Bibbs	2	3	4
Bathtub Bibbs	3	4	6
Shampoo Spray	½	1	2
Liver Spray	1	2	3
Shower Baths			
4 Inch Rain Heads	2	3	4
6 Inch Rain Heads	2	3	5
8 Inch Rain Heads	4	6	8
8 Inch Tubular Heads	6	8	10
Needle Baths	20	30	40
Manicure Tables	1	1½	2

*Compiled from tests on water pressure of 30 pounds per square inch.

1. Fair flow—stream just large enough to render good service.
2. Good flow—generally satisfactory flow.
3. Excellent flow—such flow which when increased to any great strength causes annoyance by splashing and noise.

RAPID SURVEY METHOD OF GAS REQUIREMENTS AND COSTS

In many of its phases, the selling of gas heat is very much like other specialty selling where the cost of the item or of the service to be furnished depends on the particular conditions surrounding the individual prospect.

The estimate of annual operating cost for one prospect may figure only $50.00, whereas that for another would be $500.00. When the one in the $500.00 class first makes inquiry about gas heat, his interest may be based on thinking in terms of $50.00. Likewise, the one who is in the $50.00 class may not have exhibited any interest, because he was thinking in terms of $500.00.

A method, therefore, whereby the salesman in the field can figure the estimate with reasonable accuracy and in just a few minutes time, is of great assistance in qualifying prospects. Such a method can be made sufficiently accurate to justify the salesman in attempting to close the order on the basis of the rapid survey method. If successful, then before the installation is made, his engineering department, if it so desires, can make a more elaborate survey and estimate. This can be done as if it is merely a part of the usual installation routine, so that the customer's confidence in the salesman is not affected in any way. Should this detailed survey show any glaring discrepancies, the matter can be taken up with the customer in advance of installation, so that no one will be unfavorably affected.

To show how such a rapid survey can be developed, the starting point is the formula used by heating engineers in figuring the seasonal operating cost to take care of any given area of wall, ceiling, or floor.

FORMULA

$$\text{(Heat loss in Btu per Hour)}\quad \text{Area} \times \frac{\text{Heat Transfer Coefficient} \times \text{Temp. Rise} \times \text{Hrs. Heated} \times \text{Degree Days} \times \text{Gas Rate in Cts. Per M Cu. Ft.}}{\text{Temperature Rise} \times \text{Btu Heat Content} \times \text{Efficiency} \times 1000 \times 100} = \text{Season's Operating Cost in Dollars for that Area}$$

While there are many factors in the long formula, examination will show that for any certain type of construction practically all of them are constant for any given territory. The coefficient of any certain material is always the same—the temperature rise is nearly always figured at 70 degrees—the temperature differential between basement and house interior 20 degrees—and between interior and attic 35 degrees—the number of hours per day is always 24—the number of degree days for any given territory is regarded as a constant—the gas rate and the Btu content are constant for a territory. While the efficiency factor may vary slightly with different types of equipment, an average efficiency of 75 per cent can be used for reasonably accurate results. This means that all of the factors in that long formula can be condensed for any territory into one single factor for each type of construction. Then it is simply a case of multiplying the given area by one factor instead of working out the entire formula shown above.

Another point of simplification is to measure the house as a whole rather than to measure the individual rooms. It is simple for the salesman to compute the volume by measuring the width, height, and depth of the house. Naturally, if the prospect states that certain rooms have not been heating satisfactorily with the old furnace equipment, then individual rooms should be measured and duct work or radiation checked. Just as in the case of figuring the heat loss through the walls, ceiling, or floor, this volume can be multiplied by a single constant to determine the seasonal operating cost for offsetting loss by infiltration.

With the above thought in mind, a single factor, which for purposes of clarity in explaining is called factor "F," has been worked out for the most commonly encountered types of construction. To convert this factor "F" into the correct constant for any territory, it is only necessary to multiply it by a certain multiplier, designated as "M," with "M" being determined as follows:

$$M = \frac{\text{Local Degree Days} \times \text{Average Local Heating Rate in Cents per M/Cu. Ft.}}{\text{Btu Content of Local Gas}}$$

or

$$M = \frac{\text{Local Degree Days} \times \text{Rate per Therm in Cents}}{100{,}000}$$

The following table gives the factor "F" for the most usual types of building constructions. Figure local multiplier, "M," as outlined above, multiply M by F and then it is possible to fill in this table with the local constant which will be used in figuring the seasonal operating cost to offset the heat loss through any given area of wall, ceiling, or floor.

Type of Material	*Factor "F"*	*Multiplier "M"*	*Final Constant*
Single Glass	0.000352	.....	.....
Double Glass	0.000143	.....	.....
Walls:			
8" Brick, Sheathing, Stud, L&P	0.000085	.....	.....
Stucco, Wood & Plaster	0.000099	.....	.....
Stone, Tile, Furred, L&P	0.000077	.....	.....
Clapboards, Studding, L&P	0.000080	.....	.....
Floors:			
Wood Floor. No Ceiling Below	0.000042	.....	.....
Double Floor. L&P Below	0.000022	.....	.....
Ceilings:			
Plaster Board & Plaster	0.000098	.....	.....
Rigid Insulation & Plaster	0.000056	.....	.....
Roofs:			
Tile or Slate on Wood	0.000179	.....	.....
Shingles, Sheathing, Stud, L&P	0.000102	.....	.....
Volume:			
To offset air infiltration:			
One air change per hour	0.0000058	.....	.....
One and one-half air changes	0.0000087	.....	.....
Two air changes per hour	0.0000116	.....	.....

Note: For any wall construction not listed above which may be found to be common in the locality, the factor "F" may be obtained by:

Coefficient of Transmission $\times$ 0.00032 = F

After the above final constants for the territory have been worked out, it is recommended that they be printed on a survey card arranged along the lines of the one reproduced here. The reverse side of the card can carry the usual general information as to the prospect's name and address, date of survey, and the like.

With permission, from Surface Combustion Corp.

Suggested Form For Rapid Survey Method

Area Sq. Ft.	*Material*	*Local Factor*	*Operating Cost Per Season*
.....	Glass: Single	.....	$ .....
.....	Glass: Double	.....	.....
.....	Walls (Net): 8″ Brick	.....	.....
.....	Stucco, Tile & Plaster	.....	.....
.....	Stone, Tile, Furred, L&P	.....	.....
.....	Clapboards, Studding, L&P	.....	.....
.....	.....	.....	.....
.....	Floors: Wood floor, no ceil. below ...	.....	.....
.....	Double floor: L&P below joists ...	.....	.....
.....	.....	.....	.....
.....	Roofs: Tile or slate on wood	.....	.....
.....	Shingles, Sheathing, Studding, L&P	.....	.....
.....	.....	.....	.....
Cu. Ft.	*Volume*		
.....	Infiltration: 1 air change per hr	.....	.....
.....	1½ air changes per hr	.....	.....
.....	2 air changes per hr	.....	.....
	Total Operating Cost Per Season	.....	$ .....

If Btu. heat loss per hour is desired, use formula $= \frac{218{,}750 \times \text{Season's Cost}}{M}$

Example

CONDITIONS

Assume the following conditions for the computation of the seasonal operating cost in a home:

Two and one-half story residence
Walls: 8″ brick, lath and plaster inside over sheathing
Ceilings second floor: Plaster board and plaster
No flooring in attic
Floors: Frame construction, single thickness
Single glass windows
Air changes per hour: 1
Gross wall area:
- First floor, 1300 sq. ft.
- Second floor, 1150 sq. ft.

Glass area:
- Windows and doors
- First floor, 190 sq. ft.
- Second floor, 130 sq. ft.

Area second floor ceiling: 1010 sq. ft.
Area first floor: 1010 sq. ft.
Cubical contents:
- First floor, 9100 cu. ft.
- Second floor, 8700 cu. ft.

Degree days 6000
Gas rate 40c/M cu. ft.
Btu content 530

PRELIMINARY

$$M = \frac{6000 \times 40}{530} = 453$$

Final constant for glass area	=	.000352	× 453 =	.159
Final constant for wall area	=	.000085	× 453 =	.0385
Final constant for floor area	=	.000042	× 453 =	.019
Final constant for ceiling area	=	.000098	× 453 =	.044
Final constant for infiltration	=	.0000058	× 453 =	.0026

SOLUTION

320 square feet glass area	×	.159	=	$ 50.88
2,130 square feet wall area	×	.0385	=	82.00
1,010 square feet floor area	×	.019	=	19.19
1,010 square feet ceiling area	×	.044	=	44.44
17,800 cubic feet infiltration	×	.0026	=	46.28
				$242.79

RELATIVE COST OF GAS AND ELECTRIC COOKING

The conclusions reached by the American Gas Association in their Bulletin No. 6 are as follows:

Item	Scope of Test	Energy Ratio
1.	Top burner performance	1.532
2.	Oven performance	2.624
3.	Week's menu (upper income)	2.077
4.	Week's menu (limited income)	1.799
5.	Food for Infant	1.754

Accepting an energy ratio of 1.9 the following formula will facilitate calculators:

$$\frac{1.9 \times 3413}{\text{B.t.u. of Gas}} = \text{cu. ft. of gas equivalent to 1 Kwh.}$$

in which if 525 Btu. per cu. ft. of gas is being burned, then by substitution

$$\frac{1.9 \times 3413}{525} = 12.35 \text{ cu. ft. of gas equivalent to 1 Kwh.}$$

With the foregoing as a basis, the tabulation below represents the "break even" gas cost per Mcf. for electricity at different costs per Kwh., fuel cost only being considered on a 1.9 energy ratio.

Cost per Kwh., Cents	Break-even Cost per Mcf. B.t.u. of Gas per Cu. Ft.					
	500	525	550	750	1000	1100
1.0	$0.77	$0.81	$0.85	$1.16	$1.54	$1.70
1.5	1.16	1.21	1.37	1.73	2.31	2.54
2.0	1.54	1.62	1.70	2.32	3.08	3.40
2.5	1.93	2.02	2.12	2.89	3.86	4.24
3.0	2.32	2.42	2.54	3.46	4.62	5.08
3.5	2.70	2.83	2.97	4.05	5.40	5.94
4.0	3.08	3.24	3.40	4.64	6.16	6.80
5.0	3.86	4.04	4.24	5.78	7.72	8.48

Charles W. Merriam, Jr.

ANALYSIS OF COMMERCIAL COOKING LOAD

So many factors influence the distribution of gas consumption in restaurants and other establishments of the same type, that average figures should be used with caution.

In the absence of more specific information the following rough estimates may be used:

Hospitals—Main kitchen 40% of gas consumed (main kitchen broken up 80% on ranges and 20% on other appliances). Gas consumption per meal from 1 to 5 cu. ft.

Hotels—Ranges, 60%; baking, deep-fat, and broilers, 40%. Gas consumption per meal from 10 to 25 cu. ft.

First Class Restaurants—Ranges, 40%; broilers, 10%; deep-fat fryers, 10%; steam tables and urns, 15%; short-order work, 15%; baking, 10%. Gas consumption per meal from 4 to 10 cu. ft.

Cafeteria—(All cooking done on premises). Ranges, 35%; steam tables, urns and toasters, 25%; short-order ranges, 25%; deep-fat fryers, 10%; broilers, 5%. Gas consumption per meal from 3 to 5 cu. ft.

Charles E. Lucke, Jr.

DESIRABLE HUMIDITIES FOR INDUSTRIAL OPERATIONS

Temperature varies (75°-85° F.)

Industry	*Process*	*Relative Humidity*
Cellulose	Processing and storage	35%
Confectionery	Hard candy making	40%
	Chewing gum rolling	50%
	Starch room	50%
Drugs	Powders and Tablets	30%
	Salts, Bromides and Alka Seltzer tablets	25%
Electrical	Manufacturers of electrical windings	40%
	Storage of electrical goods	40%
	Insulation windings (104° F.)	5%
Foods	Preparation of macaroni	38%
	Storage of sugar, gelatin	35%
Library or Museum	Book storage or paintings	40%
Paint	Air drying lacquers	40%
Paper	Storage and processing	40%
Photographic	Film drying	45%
Printing	Litho plate room (photo composing)	45%
	Press rooms	55%
Rubber	Dipping surgical articles	30%

FUEL CONSUMPTION OF TYPICAL FURNACES

	Btu/1000 Brick
Brick, kilns:	
Hoffman continuous kiln	3,920,000-4,760,000
Ruebon kiln	5,880,000-9,240,000
Grates and trough	4,760,000-6,300,000
Staffordshire kiln	4,760,000-6,300,000
Buhrer continuous tunnel	3,220,000-3,900,000
Metal melting:	**Btu/Ton**
Iron and steel:	
Puddling	14,000,000
Open-hearth	3,000,000-6,500,000
Air furnace for malleable castings	8,600,000
Copper, reverberatory	4,200,000
Tin, smelting	19,200,000
Rolling-mill furnaces:	
Busheling	5,600,000-7,000,000
Billet heating	2,240,000-2,520,000
Billet heating (4 by 4)	2,800,000-4,200,000
Continuous furnace (cold billets)	1,500,000-2,250,000
Continuous-bloom furnace	1,400,000-2,100,000
Reheating cold blooms	1,960,000-2,800,000
Soaking pits (hot to cold ingots)	250,000-2,000,000
Tire furnaces	4,500,000
Wheel furnaces	8,400,000
Sheet annealing	2,800,000
Tin-plate mill	2,500,000
Rivet making:	
Rivet-making furnaces	1,260,000
Forging:	
Drop forging or bolt heating	6,000,000-7,000,000
Ingot forging	4,000,000-5,000,000
Ingot forging (regeneration furnace)	3,500,000-4,000,000
Brass annealing	1,500,000-2,000,000
Heat-treatment:	
Casehardening	4,500,000-5,000,000
Quenching	2,000,000-3,000,000
Tempering	1,500,000-2,000,000

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COMPARISON OF REFRACTORIES

Chemical Classification of Refractories[1]

Acidic refractories	Fireclay
	Silica
Basic refractories	Magnesia
	Zirconia
Amphoteric refractories	Alumina
Neutral refractories	Chromite
	Graphite
	Carbon
	Carborundum and allied compounds

[1] A. B. Searle, "Refractory Materials."

PHYSICAL CLASSIFICATION OF REFRACTORIES

Refractory	PCE	High temp strength	Spalling resistance	Iron oxide slagging resistance[a]	Remarks
Silica	31–32	Excellent	Sensitive below 600°C	Fair	Widely used for sprung arches because of high-temperature strength
Fireclay	19–34	Fair	Fair Depends on manufacture	Poor	General purpose material. Inexpensive
High-alumina	Above 38	Properties improve with increasing Al_2O_3			Used for more severe conditions than fireclay will withstand
Mullite	38	Excellent	Good	Good	
Magnesite	38 and above	Good	Sensitive. Depends somewhat upon manufacture	Superior	Expensive. Used in metallurgical furnaces. High heat capacity
Forsterite	Over 32	Excellent	Good	Excellent	Indicated where both high-temperature strength and resistance to slagging are needed
Chrome	38 and above	Good	Fair to good, depending on composition and manufacture	Excellent below 2800°F. Poor above that temp	Less expensive and somewhat less slag-resistant than magnesite. Same general type of applications
Silicon carbide	37 to above 38	Excellent	Superior	Fair to poor	Expensive. Used in contact with flames and for indirect heat transfer. Abrasion-resistant

[a] Resistance to slagging does not always control uses and applications. See last column under Remarks and context of chapter.

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REPRESENTATIVE FUSION TEMPERATURES OF REFRACTORIES

	Fusing Temp, °C, of Commercial Refractories
Fused alumina	1750–2000
Bauxite	1565–2000
Mullite	1650–1820
Fireclay	1500–1750
Silica	1685–1800
Silicon carbide	1800–2240
Magnesite	2150–2165
Chrome	1850–2050
Spinel ($MgO.Al_2O_3$)	2135

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STANDARD TWIST DRILL SIZES

Designation	Diam, in.	Area, sq in.	Designation	Diam, in.	Area, sq in.	Designation	Diam, in.	Area, sq in.
1/2	0.5000	0.1963	3	0.213	0.03563	3/32	0.0938	0.00690
31/64	0.4844	0.1843	4	0.209	0.03431	42	0.0935	0.00687
15/32	0.4688	0.1726	5	0.2055	0.03317	43	0.0890	0.00622
29/64	0.4531	0.1613	6	0.204	0.03269	44	0.0860	0.00581
7/16	0.4375	0.1503	13/64	0.2031	0.03241	45	0.0820	0.00528
27/64	0.4219	0.1398	7	0.201	0.03173	46	0.0810	0.00515
Z	0.413	0.1340	8	0.199	0.03110	47	0.0785	0.00484
13/32	0.4063	0.1296	9	0.196	0.03017	5/64	0.0781	0.00479
Y	0.404	0.1282	10	0.1935	0.02940	48	0.0760	0.00454
X	0.397	0.1238	11	0.191	0.02865	49	0.0730	0.00419
25/64	0.3906	0.1198	12	0.189	0.02806	50	0.0700	0.00385
W	0.386	0.1170	3/16	0.1875	0.02761	51	0.0670	0.00353
V	0.377	0.1116	13	0.185	0.02688	52	0.0635	0.00317
3/8	0.375	0.1104	14	0.182	0.02602	1/16	0.0625	0.00307
U	0.368	0.1064	15	0.1800	0.02545	53	0.0595	0.00278
23/64	0.3594	0.1014	16	0.1770	0.02461	54	0.0550	0.00238
T	0.358	0.1006	17	0.1730	0.02351	55	0.0520	0.00212
S	0.348	0.09511	11/64	0.1719	0.02320	3/64	0.0473	0.00173
11/32	0.3438	0.09281	18	0.1695	0.02256	56	0.0465	0.001698
R	0.339	0.09026	19	0.1660	0.02164	57	0.0430	0.001452
Q	0.332	0.08657	20	0.1610	0.02036	58	0.0420	0.001385
21/64	0.3281	0.08456	21	0.1590	0.01986	59	0.0410	0.001320
P	0.323	0.08194	22	0.1570	0.01936	60	0.0400	0.001257
O	0.316	0.07843	5/32	0.1563	0.01917	61	0.039	0.001195
5/16	0.3125	0.07670	23	0.1540	0.01863	62	0.038	0.001134
N	0.302	0.07163	24	0.1520	0.01815	63	0.037	0.001075
19/64	0.2969	0.06922	25	0.1495	0.01755	64	0.036	0.001018
M	0.295	0.06835	26	0.1470	0.01697	65	0.035	0.000962
L	0.29	0.06605	27	0.1440	0.01629	66	0.033	0.000855
9/32	0.2813	0.06213	9/64	0.1406	0.01553	67	0.032	0.000804
K	0.281	0.06202	28	0.1405	0.01549	1/32	0.0313	0.000765
J	0.277	0.06026	29	0.1360	0.01453	68	0.031	0.000755
I	0.272	0.05811	30	0.1285	0.01296	69	0.0292	0.000670
H	0.266	0.05557	1/8	0.1250	0.01227	70	0.028	0.000616
17/64	0.2656	0.05542	31	0.1200	0.01131	71	0.026	0.000531
G	0.261	0.05350	32	0.1160	0.01057	72	0.025	0.000491
F	0.257	0.05187	33	0.1130	0.01003	73	0.024	0.000452
E1/4	0.2500	0.04909	34	0.1110	0.00968	74	0.0225	0.000398
D	0.246	0.04753	35	0.1100	0.00950	75	0.021	0.000346
C	0.242	0.04600	7/64	0.1094	0.00940	76	0.020	0.000314
B	0.238	0.04449	36	0.1065	0.00891	77	0.018	0.000254
15/64	0.2344	0.04314	37	0.1040	0.00849	78	0.016	0.000201
A	0.234	0.04301	38	0.1015	0.00809	1/64	0.0156	0.000191
1	0.228	0.04083	39	0.0995	0.00778	79	0.0145	0.000165
2	0.221	0.03836	40	0.0980	0.00754	80	0.0135	0.000143
7/32	0.2188	0.03758	41	0.0960	0.00724			

NOTE—Designations are in fractions of an inch, in standard twist drill letters, or in standard twist drill numbers, the latter being the same as steel wire gauge numbers. *(Courtesy of AGA.)*

COLOR SCALE FOR TEMPERATURES

(The following color scale permits a rough approximation of high temperatures)

Color	°C	°F
Lowest visible red	475	885
Lowest visible red to dark red	475– 650	885–1200
Dark red to cherry red	650– 750	1200–1380
Cherry red to bright cherry red	750– 815	1380–1500
Bright cherry red to orange	815– 900	1500–1650
Orange to yellow	900–1090	1650–2000
Yellow to light yellow	1090–1315	2000–2400
Light yellow to white	1315–1540	2400–2800
White to dazzling white	1540 or higher	2800 or higher

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COMPOSITION OF COMMON ALLOYS[1]

	Cu	Zn	Fe	Sn	Pb	Sb	Ni	Ag	Bi	Al	Remarks
Acid-resisting metal	83.05	6.00	.....	10.81	0.10	.....	.....	.....	.....	.....	Recommended for use with acid mine water
Admiralty brass	61.7	36.9	.....	1.4	.....	.....	.....	.....	.....	.....	Melts at 1570° F
Aich's metal	60.00	38.12	1.50	.....	.....	.....	.....	.....	.....	.....	This and Sterro's metal are remarkable for their great tensile strength, 85,000 lb per sq in.
Ajax plastic bronze	65.00	.....	.....	5.00	30.00						
Alkali-resisting metal	.....	.....	95.00	.....	.....	.....	5.00	.....	.....	.....	For soap factories, etc.
Anti-friction metal	5.00	85.00									
Ashberry	.....	2.80	.....	77.80	.....	19.40					
Babbitt's (original)	4.00	69.00	.....	19.00	5.00	3.00					
German railways	5.60	.....	.....	83.30	.....	11.10	.....	.....	.....	.....	S.A.E. specification says Sb, 9%; Cu, 7%
hard	8.00	.....	.....	88.00	.....	4.00					
normal	3.00	.....	.....	90.00	.....	7.00					
soft	3.00	.....	.....	84.00	5.60	7.40					
Swiss railways	10.00	.....	.....	80.00	.....	10.00					
Bell metal	80.00	.....	.....	20.00							
Berlin argentan	52.00	22.00	.....	.....	.....	.....	26.00				
Brass, cartridge	66.66	33.34	.....	.....	.....	.....	.....	.....	.....	.....	Yellow brass for plumbers' use may carry up to 4% lead in this mixture. Without lead melts at about 1650°
high	61.50	38.50	.....	.....	.....	.....	.....	.....	.....	.....	Typical brass. The high brass for naval use may carry 1% Sn, and melts at 1570°
low	80.00	20.00	.....	.....	.....	.....	.....	.....	.....	.....	
red	85.00	5.00	.....	5.00	5.00	.....	.....	.....	.....	.....	Melts at 1780° F
solder	33.00	67.00	.....	.....	.....	.....	.....	.....	.....	.....	Or may be 50% Cu, 50% Zn
Britannia, casting	0.20	.....	.....	90.60	.....	9.20	.....	.....	.....	.....	Some makers say 0.15% Mn improves the grain
sheet	1.50	.....	.....	90.60	.....	7.80					
spinning	1.00	.....	.....	94.00	.....	5.00					
Bronze, bearing metal	80.00	7.00	.....	13.00							
bearing metal	90.00	7.00	.....	3.00							
British coinage	95.00	1.00	.....	4.00							
Chinese art	74.00	10.00	.....	1.00	15.00						
Japanese art	82.70	1.80	.....	.....	4.70						
Japanese art	71.40	6.00	.....	.....	5.90						
leaded	80.00	.....	.....	10.00	10.00	.....	.....	.....	.....	.....	Melts at 1735° F
tobin	58.22	39.48	.....	2.30							
U. S. Naval	88.00	2.00	.....	10.00	.....	.....	.....	.....	.....	.....	Not over 0.3% Pb. English gear bronze is Cu 88.70, Sn 11.00, P 0.30
valve	90.00	6.00	.....	.....	4.00	.....	.....	.....	.....	.....	Material should be capable of being peened and hammered
Camelia metal	70.20	10.20	0.55	4.25	14.75						
Coin, silver, U. S.	10.00	.....	.....	.....	.....	.....	.....	90.00			
Constantan	60.00	.....	.....	.....	.....	.....	40.00				
Cupromagnesium	90.00	.....	.....	.....	.....	.....	.....	.....	Mg 10.00	.....	Used as a deoxidizer; density 8.4, melts 1290° C
Darcet's metal	.....	.....	.....	25.00	25.00	.....	.....	.....	50.00	.....	Melts at 93° C
Delta metal	55.10	43.47	1.08	.....	0.37	.....	.....	.....	.....	.....	Practically same as Sterro's metal
Dewrance metal	22.2	.....	.....	33.3	.....	44.5					
Duralumin	3.00	.....	.....	.....	.....	.....	Mn 1.0	Mg 0.5	.....	95.5	May contain some Fe and Si from the Al
Fontaine-Moreau's bronze	4.50	94.00	0.50								
Fusible metal	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	See Darcet's, Guthrie's, Lipowitz's, Lichtenburg's, Newton's, Onion's, Rose's, Wood's metals
German silver (English)	61.30	19.10	.....	.....	.....	.....	Ni 19.10				
Gun metal	92.50	2.50	.....	5.00							
Gun metal	91.00	2.00	.....	7.00							
Gun metal	87.75	2.50	.....	9.75	.....	.....	.....	.....	.....	.....	Melts at 1825° F
Gun metal	85.00	10.00	.....	5.00	.....	.....	.....	.....	.....	.....	With 3% Pb, melts at 1795° F
Gun metal	83.00	15.00	.....	2.00							
Gurley's metal	86.50	5.40	.....	5.40	2.70	.....	.....	.....	.....	.....	Used for transit frames
Guthrie's metal	.....	.....	.....	19.97	19.36	.....	.....	Cd 13.29	47.38	.....	Melts at 160° F

Guthrie's metal 13.29

	Cu	Zn	Fe	Sn	Pb	Sb	Ni	Ag	Bi	Al	Remarks
Hardware metal	50.00	34.90	.....	.....	.....	.....	15.00	.....	.....	0.10	Harness trimmings, etc. Casts well. Doesn't roll
Hydraulic bronze	75.00	14.00	.....	11.00							
Hydraulic bronze	83.00	5.00	.....	5.00	5.00	.....	2.00	.....	.....	.....	For pressures up to 3000 lb per sq in.
Jacoby metal	5.00	.....	.....	85.00	.....	10.00					
Lichtenberg's metal	.....	.....	.....	20.00	30.00	.....	.....	.....	50.00	.....	Melts 94.5° C
Lipowitz's metal	.....	.....	.....	13.33	26.67	.....	.....	.....	50.00	Cd 10.00	Melts 70° C
Mackenzie's alloy	.....	.....	.....	.....	68.00	16.00	.....	.....	16.00	.....	Stereotype metal
Magnolia metal	.....	.....	.....	4.75	80.00	15.00	.....	.....	0.25	.....	Melts at 608° C., coeff. of exp. 0.000024 per C°
Manganese bronze	88.64	1.57	0.72	8.70	0.295	.....	.....	.....	.....	.....	Trace of phosphorus
Manganin	82.12	.....	0.57	.....	.....	.....	2.29	.....	Mn 15.02	.....	Practically no temperature coefficient of resistance
Mannheim gold	80.00	20.00	.....	.....	.....	.....	.....	.....	.....	.....	Practically identical with Prince's metal and Tombac
Mannheim gold	88.00	12.00									
Monel metal	33.00	.....	6.50	.....	.....	.....	60.00	.....	.....	Al 0.05	U. S. Government specifications for castings
Morin's Chinese bronze	83.00	2.00	.....	5.00	10.00						
Mosaic gold	65.00	35.00									
Muntz metal	62.00	38.00									
Muntz metal	60.00	40.00									
Needle metal	84.96	5.31	.....	7.96	1.77	.....	.....	.....	.....	.....	Extremely fluid
Newton's metal	.....	.....	.....	18.75	31.25	.....	.....	.....	50.00	.....	Melts at 94.5° C
Onion's alloy	.....	.....	.....	20.00	30.00	.....	.....	.....	50.00	.....	Melts at 197° F
Packfong	43.80	40.60	.....	.....	.....	.....	15.60	.....	.....	.....	A Chinese alloy
Parr's alloy	5.00	.....	Cr 20.00	.....	.....	.....	63.00	W 2.00	.....	Mo 5.00	Also contains Al, B, and Mn. Said to have tensile strength of 60,000 lb per sq in. and to resist acids
Pewter	1.42	.....	.....	97.00	1.65						
Phosphor bronze	80.00	.....	.....	10.00	10.00	.....	.....	.....	.....	.....	Phosphorus, 0.05–0.25%
Pinchbeck	83.33	16.76	.....	.....	.....	.....	.....	.....	.....	.....	A cheap imitation gold
Plastic bronze	65.00	.....	.....	5.00	30.00						
Platine	43.00	57.00									
Platinoid	60.00	24.00	.....	.....	.....	.....	14.00	W 2.00			
Queen's metal	3.50	0.90	.....	88.50	.....	7.10					
Red metal	70.00	20.00	.....	4.00	6.00	.....	.....	.....	.....	.....	Melts at about 1800° F
Rose's metal	.....	.....	.....	25.00	25.00	.....	.....	.....	50.00	.....	Melts at 93.75° C
Sheffield German silver	57.00	19.00	.....	.....	.....	.....	24.00				
Silicon bronze	97.12	1.12	.....	1.14	.....	.....	.....	.....	.....	.....	Also a little silicon. Extremely high tensile strength
Solder	.....	.....	.....	33.33	66.67	.....	.....	.....	.....	.....	Sp gr 9.4; coeff. of exp., 0.000025 per °C; melts at 240° C
for German silver	45.00	45.00	.....	.....	.....	.....	10.00	.....	.....	.....	Melts easily, flows well
hard for silver	13.00	7.00	.....	.....	.....	.....	.....	80.00			
soft for silver	28.00	11.00	.....	4.00	.....	.....	.....	57.00			
Sterline	68.52	12.84	0.76	.....	tr.	17.88	.....	.....	.....	.....	Imitation silver for forks, etc.
Sterro's metal	55.33	41.80	4.66								
Tantiron	.....	.....	83.50	.....	C 1.0	.....	Si 15.0	.....	.....	.....	Highly resistant to corrosion by acid
Tobin bronze	58.22	39.48	.....	2.30							
Tombac, English	86.38	13.61									
Viennese	97.80	2.20									
Trolley-wheel bronze	92.00	2.00	.....	6.00	none						
Turbadium bronze	48.00	46.45	1.00	0.50	0.10	.....	2.00	Mn 1.75	.....	0.20	Used for propeller castings
Turbine-wheel mixture	86.77	3.48	.....	8.68	1.07	.....	.....	.....	.....	.....	Not so likely to have blow holes as M n bronze
Type metal	.....	.....	.....	3.00	82.00	15.00					
Victor metal	49.94	34.27	0.28	.....	.....	.....	15.40	.....	.....	0.11	Resists salt air
Watchmaker's alloy	58.86	40.22	.....	.....	1.90	.....	.....	.....	.....	.....	An imitation gold
White brass	3–6	28–30	.....	65.00	.....	.....	.....	.....	.....	.....	Good bearing in automobile engines
Wood's metal	.....	.....	.....	12.50	25.00	.....	.....	Cd 12.50	50.00	.....	Melts at 60.5° C

[1]Liddell, "Metallurgists and Chemists' Handbook," McGraw-Hill.

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THERMAL PROPERTIES OF METALS

Substance	Composition	Density lb/cu ft	Mean specific heat, 60°to melting point (Btu/lb)	Latent heat of fusion Btu/lb	Mean specific heat of liquid Btu/lb °F	Melting point °F	Average pouring temp °F	Ht content of solid at melting point Btu/lb	Ht content of liquid at melting temp Btu/lb	Ht content of liquid at pouring temp Btu/lb
Aluminum	Al	166.7	0.248	169.0	0.26	1215	1380	286.0	455.0	497.0
Babbitt, Lead Base	75 Pb, 15 Sb, 10 Sn	....	0.039	26.2	0.038	462	625	15.8	42.0	48.0
Babbitt, Tin Base	83.3 Sn, 8.4 Sb, 8.3 Cu	462	0.071	34.1	0.063	464	916	28.6	67.7	91.0
Bismuth	Bi	612	0.033	18.5	0.035	518	620	15.1	33.6	37.2
Brass, Muntz Metal	60 Cu, 40 Zn	524	0.105	69.0	0.125	1630	1850	165.0	234.0	261.0
Brass, Red	90 Cu, 10 Zn	546	0.104	86.5	0.115	1952	2250	197.0	283.5	317.8
Brass, Yellow	67 Cu, 33 Zn	528	0.105	71.0	0.123	1688	1950	171.0	242.0	274.2
Bronze, Aluminum	90 Cu, 10 Al	510	0.126	98.6	0.125	1922	2200	235.0	333.6	368.0
Bronze, Bearing	80 Cu, 10 Pb, 10 Sn	556	0.095	79.9	0.109	1832	2050	168.3	248.2	272.0
Bronze, Bell Metal	78 Cu, 22 Sn	540	0.100	76.3	0.119	1634	1900	157.4	233.7	265.4
Bronze, Gun Metal	90 Cu, 10 Sn	550	0.107	84.2	0.106	1850	2100	191.5	275.7	302.0
Bronze, Tobin	60 Cu, 39.2 Zn, 0.8 Sn	525	0.107	73.5	0.124	1625	1850	167.5	241.0	268.9
Copper	Cu	559	0.104	91.0	0.111	1982	2200	200.0	291.0	315.0
Die Casting Metal	92 Al, 8 Cu	176	0.236	163.0	0.241	1150	1400	257.3	420.3	481.0
Die Casting Metal	80 Pb, 10 Sn, 10 Sb	....	0.038	17.5	0.037	600	820	20.5	38.0	146.0
Die Casting Metal	90 Sn, 4.5 Cu, 5.5 Sb	....	0.070	30.2	0.062	450	650	27.6	57.6	70.0
Die Casting Metal	87.3 Zn, 8.1 Sn, 4.1 Cu, 0.5 Al	....	0.103	48.0	0.138	780	980	74.0	122.0	150.0
German Silver	60 Cu, 25 Zn, 15 Ni	....	0.109	86.2	0.123	1850	2100	194.0	280.2	311.0
Gold	Au	1205	0.033	28.5	0.034	1945	2150	62.2	90.7	97.7
Iron 60° to 2786° F	Fe	491	0.165	89.0	0.150	2786	2912	447.0	536.0	555.0
Lead	Pb	708	0.032	10.0	0.034	621	720	18.0	28.0	31.0
Linotype	86 Pb, 11 Sb, 3 Sn	....	0.036	21.5	0.036	486	620	15.3	36.8	41.6
Magnesium	Mg	108.6	0.272	83.7	0.266	1204	1380	311.2	394.9	441.7
Manganese	Mn	464	0.171	66.0	0.192	2246	2400	374.0	440.0	469.0
Monel Metal	67Ni, 28 Cu; Fe, Mn, Si	550	0.129	117.4	0.139	2415	2750	304.0	421.4	468.0
Nickel 60° to 2644 °F	Ni	556	0.134	131.5	0.133	2644	2850	346.0	477.5	505.0
Silver	Ag	655	0.063	46.8	0.070	1762	1950	107.0	153.8	167.0
Solder, Bismuth	40 Pb, 20 Sn, 40 Bi	....	0.040	16.4	0.039	232	330	9.3	25.7	29.5
Solder, Plumbers'	50 Pb, 50 Sn	580	0.051	23.0	0.049	414	500	18.0	41.0	45.0
Tin	Sn	455	0.069	25.0	0.0637	450	650	27.0	52.0	64.0
Zinc	Zn	445	0.107	48.0	0.146	786	900	77.8	125.8	142.0

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APPROXIMATE TEMPERATURES FOR INDUSTRIAL HEATING PROCESSES AND OPERATIONS

Material	Operation	Approximate temperature, °F
Aluminum	Forging	970
	Melting	1380
Brass	Forging	1400
	Melting	2100
Bread	Baking	500
Brick (common)	Burning	1900
(fire clay)	Burning	2200
(silica)	Burning	2700
Cement	Calcining	2800
Copper	Forging	1800
	Melting	2200
	Smelting	2800
Enamel (vitreous)	Enameling	1800
Frit	Smelting	2200
Glass	Melting	2400
Iron	Melting (cupola)	2700
	Smelting (blast furnace)	3000
Lead	Melting	720
	Smelting	2200
Lime	Burning	2100
Sand, Core (foundry)	Core baking	450
Steel	Annealing (castings)	1650
	Annealing (sheet)	1700
	Carburizing	1650
	Case hardening	1700
	Drawing	900
	Forging	2200
	Hardening (carbon steels)	1550
	Hardening (high speed steels)	2300
	Heating for forming	1900
	Heating for rolling	2400
	Melting (open hearth, crucible)	2900
	Nitriding	950
Varnish	Cooking	550
Zinc	Galvanizing	850
	Melting	950

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DEGREE DAYS AND MINIMUM TEMPERATURES FOR CITIES OF UNITED STATES AND CANADA[1]

City	Min. temp.	Degree-days
Alabama		
Anniston	3	2813
Gadsden	—13	3006
Montgomery	— 5	1886
Ozark	10	1735
Tuscaloosa	— 7	2529
Arizona		
Flagstaff	—25	7145
Tucson	6	1845
Arkansas		
Bergman	—17	3956
Little Rock	—12	2811
Texarkana	— 7	2216
California		
Bakersfield	13	2047
Fresno	17	2375
Los Angeles	28	1504
Pasadena	21	2066
Sacramento	19	2654
San Diego	25	1645
San Francisco	29	3264
Colorado		
Buena Vista	—37	8849
Colorado Springs	—27	6553
Denver	—29	5873
Pueblo	27	5514
Connecticut		
Hartford	—18	6037
New Haven	—14	5895
Delaware		
Wilmington	—12	4788
District of Columbia		
Washington	—15	4626
Florida		
Monticello	16	1129
Tampa	9	296
Georgia		
Atlanta	— 8	2891
Augusta	3	2161
Macon	— 4	2203
Rome	— 7	3067
Savannah	8	1490
Idaho		
Boise	—28	4558
Springfield	—28	7477
Illinois		
Chicago	—23	6315
Joliet	—25	6535
Springfield	—24	5370
Indiana		
Evansville	—16	4164
Fort Wayne	—24	5916
Indianapolis	—25	5297
South Bend	—20	6076
Terre Haute	—18	4871
Iowa		
Davenport	—27	6287
Des Moines	—30	6373
Dubuque	—32	6788
Mason City	—35	7571
Sioux City	—35	7023
Kansas		
Emporia	—23	4792
Topeka	—25	5301
Wichita	—22	4877
Kentucky		
Lexington	—20	4616
Louisville	—20	4180
Louisiana		
Baton Rouge	2	1349
New Orleans	7	1023
Shreveport	— 5	1938
Maine		
Bar Harbor	—21	7643
Portland	—21	7012
Maryland		
Baltimore	— 7	4333
Frederick	No fig.	5928
Massachusetts		
Boston	—14	6145
Fitchburg	—17	6732
Williamstown	—26	7221
Michigan		
Ann Arbor	—21	6865
Cadillac	—36	7967
Detroit	—28	6494
Grand Rapids	—24	6534
Kalamazoo	—25	6652
Lansing	—26	7112
Sault Ste. Marie	—37	9281
Minnesota		
Duluth	—41	9480
Minneapolis	—33	7851
Rochester	—42	8123
Mississippi		
Columbia	9	1740
Corinth	— 8	3411
Tupelo	— 7	2780
Vicksburg	— 1	1809
Missouri		
Grant City	—29	5659
Jefferson City	—25	4874
Kansas City	—22	5202
St. Louis	—22	4585
Montana		
Billings	—49	7115
Butte	—33	8271
Helena	—42	8054
Nebraska		
Dumas	—31	7203
Omaha	—32	6128
Nevada		
Las Vegas	8	2842
Reno	—19	5891
New Hampshire		
Concord	—35	6852
Hanover	—37	8063
Keene	—28	7457
New Jersey		
Atlantic City	— 7	5175
Dover	—21	5970
Newark	—13	5387
New Brunswick	—15	5405
Sussex	—24	6134
Trenton	—13	4934

[1] From AGA "Househeating" and U.S. Weather Bureau.

City	Min. temp.	Degree-days
New Mexico		
Albuquerque	—10	4303
Santa Fe	—13	6063
New York		
Albany	—24	6889
Buffalo	—14	6821
Ithaca	—22	6719
New York City	—13	5348
Ogdensburg	—43	7490
Plattsburg	—25	7894
Rochester	—14	6733
Saranac Lake	—39	8673
Syracuse	—22	6592
North Carolina		
Asheville	No fig.	4263
Greensboro	— 3	3527
Wilmington	5	2302
North Dakota		
Bismarck	—45	8498
Hannah	—54	10714
Ohio		
Akron	—20	6069
Cincinnati	—17	4702
Cleveland	—17	6154
Columbus	—20	5323
Dayton	—16	5274
Oklahoma		
Hugo	— 3	2648
Oklahoma City	—17	3613
Tulsa	—15	3560
Oregon		
Portland	— 2	4468
Wallowa	—38	7360
Pennsylvania		
Erie	—16	5866
Gettysburg	—20	5580
Philadelphia	— 6	4855
Pittsburgh	—20	5235
Reading	—14	5388
Scranton	—15	6129
Rhode Island		
Providence	—12	6014
South Carolina		
Charleston	7	1769
Columbia	— 2	2364
Spartanburg	— 4	3257
South Dakota		
Aberdeen	—46	8709
Jefferson	—48	8419
Tennessee		
Knoxville	—16	3670
Memphis	— 9	2950
Nashville	—13	3578
Texas		
Austin	— 1	1578
Dallas	—10	2455
Eagle Pass	— 7	871
Galveston	8	1016
Houston	6	1157
San Antonio	4	1202
Utah		
Provo	—23	6184
Salt Lake City	—20	5553
Vermont		
Burlington	—28	7620
Northfield	—41	8420
Virginia		
Fredericksburg	—21	4243
Roanoke	—12	4068
Richmond	— 3	3725
Washington		
Seattle	3	4868
Spokane	—30	6353
Walla Walla	—17	4809
West Virginia		
Charleston	—17	3786
Huntington	—24	4734
Wheeling	No fig.	5249
Wisconsin		
Green Bay	—36	7823
Milwaukee	—25	7372
Superior	—35	9750
Wyoming		
Casper	—30	6979
Cheyenne	—38	7462
Canada		
Vancouver, B. C.	...	5976
Winnipeg, Man.	...	11166
Toronto, Ont.	...	7732
Montreal, Que.	...	8705
Quebec, Que.	...	8628

ANNUITY WHICH WILL AMOUNT TO ONE DOLLAR IN A GIVEN TIME

ANNUITY APPLIED AT END OF EACH YEAR

Years	2 per cent	2½ per cent	3 per cent	3½ per cent	4 per cent	4½ per cent	5 per cent
1	$1.000000	$1.000000	$1.000000	$1.000000	$1.000000	$1.000000	$1.000000
2	0.495050	0.493827	0.492611	0.491400	0.490196	0.488998	0.487805
3	.326755	.325137	.323530	.321934	.320349	.318773	.317209
4	.242624	.240818	.239027	.237251	.235490	.233744	.232012
5	.192159	.190247	.188355	.186481	.184627	.182792	.180975
6	.158526	.156550	.154597	.152668	.150762	.148878	.147017
7	.134512	.132495	.130506	.128545	.126610	.124701	.122820
8	.116510	.114467	.112456	.110477	.108528	.106610	.104722
9	.102515	.100457	.098434	.096446	.094493	.092574	.090690
10	.091327	.089259	.087231	.085241	.083291	.081379	.079505
11	.082178	.080106	.078077	.076092	.074149	.072248	.070389
12	.074560	.072487	.070462	.068484	.066552	.064666	.062825
13	.068118	.066048	.064030	.062062	.060144	.058275	.056456
14	.062602	.060537	.058526	.056571	.054669	.052820	.051024
15	.057825	.055766	.053767	.051825	.049941	.048114	.046342
16	.053650	.051599	.049611	.047685	.045820	.044015	.042270
17	.049970	.047928	.045953	.044043	.042199	.040418	.038699
18	.046702	.044670	.042709	.040817	.038993	.037237	.035546
19	.043782	.041761	.039814	.037940	.036139	.034407	.032745
20	.041157	.039147	.037216	.035361	.033582	.031876	.030243
21	.038785	.036787	.034872	.033037	.031280	.029601	.027996
22	.036631	.034647	.032747	.030932	.029199	.027546	.025971
23	.034668	.032696	.030814	.029019	.027309	.025682	.024137
24	.032871	.030913	.029047	.027273	.025587	.023987	.022471
25	.031220	.029276	.027428	.025674	.024012	.022439	.020952
26	.029699	.027769	.025938	.024205	.022567	.021021	.019564
27	.028293	.026377	.024564	.022852	.021239	.019719	.018292
28	.026990	.025088	.023293	.021603	.020013	.018521	.017123
29	.025778	.023891	.022115	.020445	.018880	.017415	.016046
30	.024650	.022778	.021019	.019371	.017830	.016392	.015051
31	.023596	.021739	.019999	.018372	.016855	.015443	.014132
32	.022611	.020768	.019047	.017442	.015949	.014563	.013280
33	.021687	.019859	.018156	.016572	.015104	.013745	.012490
34	.020819	.019007	.017322	.015760	.014315	.012982	.011755
35	.020002	.018206	.016539	.014998	.013577	.012270	.011072
36	.019233	.017452	.015804	.014284	.012887	.011606	.010434
37	.018507	.016741	.015112	.013613	.012240	.010984	.009840
38	.017821	.016070	.014459	.012982	.011632	.010402	.009284
39	.017171	.015436	.013844	.012388	.011061	.009856	.008765
40	.016556	.014836	.013262	.011827	.010523	.009343	.008278
41	.015972	.014268	.012712	.011298	.010017	.008862	.007822
42	.015417	.013729	.012192	.010798	.009540	.008409	.007395
43	.014890	.013217	.011698	.010325	.009090	.007982	.006993
44	.014388	.012730	.011230	.009878	.008665	.007581	.006616
45	.013910	.012268	.010785	.009453	.008262	.007202	.006262
46	.013453	.011827	.010363	.009051	.007882	.006845	.005928
47	.013018	.011407	.009961	.008669	.007522	.006507	.005614
48	.012602	.011006	.009578	.008306	.007181	.006189	.005318
49	.012204	.010623	.009213	.007962	.006857	.005887	.005040
50	.011823	.010258	.008865	.007634	.006550	.005602	.004777

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ANNUITY WHICH WILL AMOUNT TO ONE DOLLAR IN A GIVEN TIME (Concluded)

ANNUITY APPLIED AT END OF EACH YEAR

Years	5½ per cent	6 per cent	6½ per cent	7 per cent	8 per cent	9 per cent	10 per cent
1	$1.000000	$1.000000	$1.000000	$1.000000	$1.000000	$1.000000	$1.000000
2	0.486618	0.485437	0.484262	0.483092	0.480769	0.478469	0.476190
3	.315664	.314110	.312576	.311052	.308034	.305055	.302115
4	.230295	.228591	.226903	.225228	.221921	.218669	.215471
5	.179173	.177396	.175635	.173891	.170456	.167092	.163797
6	.145179	.143363	.141568	.139796	.136315	.132920	.129607
7	.120964	.119135	.117331	.115553	.112072	.108691	.105408
8	.102864	.101036	.099237	.097468	.094015	.090674	.087444
9	.088839	.087022	.085238	.083486	.080080	.076799	.073641
10	.077668	.075868	.074105	.072378	.069029	.065820	.062745
11	.068571	.066793	.065055	.063357	.060076	.056947	.053963
12	.061029	.059277	.057568	.055902	.052695	.049651	.046763
13	.054684	.052960	.051283	.049651	.046522	.043567	.040779
14	.049279	.047585	.045940	.044345	.041297	.038433	.035746
15	.044626	.042963	.041353	.039795	.036830	.034059	.031474
16	.040583	.038952	.037378	.035858	.032977	.030300	.027817
17	.037042	.035445	.033906	.032425	.029629	.027046	.024664
18	.033920	.032357	.030855	.029413	.026702	.024212	.021930
19	.031150	.029621	.028156	.026753	.024128	.021730	.019547
20	.028679	.027185	.025756	.024393	.021852	.019546	.017460
21	.026465	.025005	.023613	.022289	.019832	.017617	.015624
22	.024471	.023046	.021691	.020406	.018032	.015905	.014005
23	.022670	.021278	.019961	.018714	.016422	.014382	.012572
24	.021036	.019679	.018398	.017189	.014978	.013023	.011300
25	.019549	.018227	.016981	.015811	.013679	.011806	.010161
26	.018193	.016904	.015695	.014561	.0125071	.0107154	.0091590
27	.016952	.015697	.014523	.013426	.0114481	.0097349	.0082576
28	.015814	.014593	.013453	.012392	.0104889	.0088520	.0074510
29	.014769	.013580	.012474	.011449	.0096185	.0080557	.0067281
30	.013805	.012649	.011577	.010586	.0088274	.0073364	.0060792
31	.012917	.011792	.010754	.009797	.0081073	.0066856	.0054962
32	.012095	.011002	.009997	.009073	.0074508	.0060962	.0049717
33	.011335	.010273	.009299	.008408	.0068516	.0055617	.0044994
34	.010630	.009598	.008656	.007797	.0063041	.0050766	.0040737
35	.009975	.008974	.008062	.007234	.0058033	.0046358	.0036897
36	.009366	.008395	.007513	.006715	.0053447	.0042350	.0033431
37	.008800	.007857	.007005	.006237	.0049244	.0038703	.0030299
38	.008272	.007358	.006535	.005795	.0045389	.0035382	.0027469
39	.007780	.006894	.006099	.005387	.0041851	.0032356	.0024910
40	.007320	.006462	.005694	.005009	.0038602	.0029596	.0022594
41	.006891	.006059	.005318	.004660	.0035615	.0027079	.0020498
42	.006489	.005683	.004968	.004336	.0032868	.0024781	.0018600
43	.006113	.005333	.004644	.004036	.0030341	.0022684	.0016880
44	.005761	.005006	.004341	.003758	.0028015	.0020767	.0015322
45	.005431	.004700	.004060	.003500	.0025873	.0019017	.0013910
46	.005122	.004415	.003797	.003260	.0023899	.0017416	.0012620
47	.004831	.004148	.003553	.003037	.0022080	.0015952	.0011468
48	.004559	.003897	.003325	.002831	.0020403	.0014614	.0010415
49	.004302	.003664	.003112	.002639	.0018856	.0013389	.0009459
50	.004061	.003444	.002914	.002460	.0017429	.0012269	.0008592

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Interchangeability of Various Gases

BY interchangeability of gases is meant the possibility of using a substitute gas for the gas usually distributed for domestic and industrial consumption without interfering with the operation of appliances used by the consumer.

The subject is complicated by many factors such as heating value, specific gravity, and composition of the various gases under consideration.

The present supply of natural gas has resulted and probably will continue to result in the distribution in many cities of gases of rather high heating value; in many cases, of straight natural gas having a heating value in excess of 1000 Btu per cubic foot.

The American Gas Association has conducted considerable research on the general subject of interchangeability of gases. When it began reviewing the subject of a substitute gas for straight natural gas, it was found that none of the formulae developed earlier for the interchangeability of mixed gases of lower heating value were applicable to the interchangeability of the higher heating value gases. It became necessary to find new equations which would take into consideration all factors affecting interchangeability.

Interchangeability Factors

It was concluded that interchangeability of higher heating-value gases could be best mathematically treated if considered from three distinct viewpoints, that is, the tendency of high heating value supplemental gases to—

(1) lift
(2) flashback
(3) produce yellow tips.

The speed of flame propagation, or ignition velocity, is very important in consideration of the burning characteristics of different gases.

Fast-burning constituents, such as hydrogen and acetylene, accelerate the rate of flame propagation with a tendency toward flashback, whereas slow-burning constituents, such as methane and illuminants, produce little tendency to flashback but may result in lifting of the flame.

An equation to predict occurrence of lifting as a result of interchange of gases was developed which takes into consideration change in input-rate and primary-air injection resulting from the substitution as well as differences in lifting characteristics of the two gases. The index of lifting interchangeability, I_L, is the result obtained from calculation of the lifting interchangeability equation—

$$I_L = \frac{K_a}{\frac{f_a}{f_s}\,\frac{a_s}{a_a}\left(K_s\text{-log}\,\frac{f_a}{f_s}\right)}$$

An empirical expression was developed to denote the tendency of burners to flashback as a result of interchanging a supplemental gas for natural gas. The index of flashback interchangeability, I_F, is the result obtained from calculation of the flashback interchangeability equation—

$$I_F = \frac{K_s}{K_a}\,\frac{f_s}{f_a}\,\sqrt{\frac{h_s}{1000}}$$

An equation was developed for determining conditions of interchange which would result in yellow-tip formation. This equation takes into consideration changes in primary-air injection and yellow-tip limit resulting from substitution of one gas for another. Calculation of this equation gives value for the index of yellow-tip interchangeability, I_Y.

$$I_Y = \frac{f_s}{f_a}\,\frac{a_a}{a_s}\,\frac{Y_a}{Y_s}$$

Obtaining Values For Equation Characters

In order to obtain values for the characters in these three equations, certain other equations must be employed, as follows:

Air theoretically required for complete combustion,

$$\text{per 100 Btu } a_a = \frac{100\,A_a}{h_a}$$

$$\text{Primary air factor } f_a = \frac{1000\sqrt{d_a}}{h_a}$$

$$\text{Lifting limit constant } K_a = \frac{F_a}{d_a}$$

Yellow-tip limit

$$Y_a = \frac{100\,T_a}{A_a + 7E_a - 26.3\,0_{2a}}$$

The nomenclature for the above equations follows—

A = air theoretically required for complete combustion, cubic feet per foot of gas
a = air theoretically required for complete combustion, cubic feet per 100 Btu of gas
d = specific gravity (air = 1.0)
E = total inerts in gas mixture, decimal volume
F = lifting constant
f = primary-air factor
h = gross heating value, Btu per cubic foot
I_F = index of flashback interchangeability
I_L = index of lifting interchangeability
I_Y = index of yellow-tip interchangeability
K = lifting-limit constant
O_2 = oxygen in gas mixture, decimal volume
T = yellow-tip constant, cubic feet of air required to eliminate yellow tips per cubic foot of gas
Y = yellow-tip limit, percent primary air
Subscript a = adjustment gas
Subscript s = substitute (or supplemental) gas.

Type of Natural Gas Normally Distributed

In this work the American Gas Association assumed that one of the three types of natural gas presented below would be the adjustment gas or the gas normally distributed.

		High Btu Nat. Gas	High Methane Nat. Gas	High Inert Nat. Gas
Carbon dioxide	CO_2	0.5%	0.0%	0.5%
Methane	CH_4	83.0	94.5	71.4
Ethane	C_2H_6	16.0	0.0	14.0
Propane	C_3H_8	0.0	0.0	1.0
Nitrogen	N_2	0.5	5.5*	13.1
B.t.u./cu. ft.		1115	959	1000
Sp. gr.		0.64	0.56	0.69

* Inerts.

For any proposed adjustment, or substitute gas, all three indices must fall

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within certain numerical limits, which are shown to be:

Interchangeability Index	High-Heating Value Nat. Gas		High-Methane Nat. Gas		High-Inert Nat. Gas	
	Preferable	Objectionable	Preferable	Objectionable	Preferable	Objectionable
I_L	Under 1.0	Above 1.12	Under 1.0	Above 1.06	Under 1.0	Above 1.03
I_F	Under 1.18	Above 1.2	Under 1.18	Above 1.2	Under 1.18	Above 1.2
I_T	Above 1.0	Under 0.7	Above 1.0	Under 0.8	Above 1.0	Under 0.9

It is stated that when burners are properly adjusted on the base-load gas, these preferable limits can be exceeded, the degree of variation depending on the adjustment natural gas.

When values of the Interchangeability Indices are intermediate between the preferable limit and the objectionable limit, each particular situation must be carefully analyzed to determine the limits of interchangeability.

The same formulae given can be used to determine the percentage of adjustment gas which must be retained in admixture with the supplemental gas to bring values of the Interchangeability Indices within desirable limits.

Appliance Tests Made

In arriving at the formulae given here, the American Gas Association Laboratories selected many critical appliances and adjusted them for a given type of natural gas. Substitute gases were then prepared and supplied to the appliances and observations made of the operating characteristics of each burner. If complete substitution of the supplemental gas resulted in unsatisfactory performance of any of the control appliances, further studies were made with portions of the base natural gas added to the supplemental gas. In this manner the limiting percentage of supplemental gas could be determined.

In this same reference a comparison is given of a burner operating on the high Btu natural gas compared to carbureted water gas of 1000 and 1200 Btu per cubic foot. It is stated that only 40 per cent of these carbureted water gases could be mixed with the original natural gas and still maintain satisfactory combustion characteristics.

Comparing Base, Supplemental Gases

It is apparent that no generalized statement can be made regarding the interchangeability of high heating-value substitute gases with natural gas. Rather, it is necessary to make a very careful comparison of the proposed supplemental gas with the base, or adjustment gas.

In order to demonstrate the manipulation of the equations outlined, a comparison has been made using as a base, or adjustment gas, a natural gas, the analysis of which is given below. It is proposed to substitute for this a high Btu oil gas of the characteristics listed—

	Natural Gas	High Btu Oil Gas
Carbon dioxide ... CO_2	0.8%	6.4%
Illuminants	0.0	25.9
Oxygen ..... O_2	0.0	0.5
Carbon monoxide . CO	0.0	0.8
Methane ..... CH_4	91.0	33.3
Ethane ..... C_2H_6	3.1	0.0
Propane ..... C_3H_8	1.7	0.0
Butane ..... C_4H_{10}	0.7	0.0
Hydrogen ..... H_2	0.0	13.4
Nitrogen ..... N_2	2.7	19.7
B.t.u./cu. ft.	1047	970
Sp. gr.	0.61	0.88

Results were as follows:

	I_L Lifting Index	I_F Flash-back Index	I_T Yellow-tip Index
100% Supplemental Gas	1.25	1.29	0.6
50% Supplemental Gas / 50% Adjustment Gas	1.11	1.16	0.7
30% Supplemental Gas / 70% Adjustment Gas	1.07	1.10	0.8

By comparison, it is seen that 100 per cent of this particular supplemental gas could not be used to replace natural gas of the type considered, since all three indices, Lifting, Flashback, and Yellow-Tip, are in the objectionable range. The mixture of 50 per cent oil gas with 50 per cent natural gas appears to be satisfactory from the standpoint of flashback. The Lifting Index and Yellow-Tip Index are almost exactly at the objectionable limits, so close that more natural gas is desirable. The mixture of 30 per cent oil gas with 70 per cent natural gas gives indices, none of which are in the objectionable range and which, in general, approximate the preferable range.

Percent of Oil Gas in Admixture

Accordingly, it is considered that 30 per cent of this oil gas could safely be used in admixture with the natural gas available. Possibly this proportion of oil gas could be exceeded, but probably not beyond 50 per cent. The proportion of this oil gas which can be used would probably be increased if the oil gas were scrubbed to remove some undesirable constituents.

The particular oil gas used in the foregoing discussion is one which has been proposed as a supplement or substitute for natural gas. The analysis used has been published. This gas is not necessarily the best or only substitute for natural gas. It is used merely to illustrate the application of equations derived for determining the interchangeability of gases of high heating-value. Later research may show that oil gases, or other gases, may be more nearly interchangeable with natural gas than is indicated by present knowledge on the subject.

A recent statement regarding research sponsored by the American Gas Association states:

> "Just initiated is a project to determine the approximate degree of compatibility of the currently produced oil gases with natural gas. These tests should indicate what further research is necessary to develop suitable substitutes for natural gas. It is possible that suitable control of the production processes will be sufficient. Possibly after-treatment with catalysts will provide the answers. Decisions as to the course of the future work must await the results of these preliminary studies."

For interchangeability of gases where the heating value of the send-out gas is rather low, in the neighborhood of 530-540 Btu other determinations have been made.

AGA "Index C" Method

In 1933 the American Gas Association, after considerable testing, evolved the so-called "Index C" calculated from a mathematical equation involving heating value, specific gravity, and chemical analysis of the base and supplemental gases. This "Index C" was supposed to be a criterion of interchangeability of gases with heating values below 700 Btu per cubic foot. If the supplemental gas had a "C" index in the range 0.85 to 1.15, it was indicated that it could replace the base gas and maintain satis-

factory appliance performance. The equation is—

$$C = \frac{h_s}{h_a}\frac{A_s}{A_a}\frac{d_a}{d_s} + (K_a - K_s)$$

where,

C = index of interchangeability
a = subscript denoting adjustment gas
s = subscript denoting substitute gas
h = gross heating value, Btu per cubic foot
A = air theoretically required for complete combustion, cubic feet per cubic foot of gas
d = specific gravity of gas (air = 1.0)

$K = \frac{hA}{5000\ E\ F}$, in which

E = the heat capacity of the theoretical products of combustion (from one cubic foot of gas) per degree F. between 60°F. and 1600°F., in Btu E is equal to 0.029 VCO_2 + 0.023 VH_2O + 0.0189 VN_2 where V is the volume in cubic feet of each product (as indicated by the subscripts) formed by the combustion of one cubic foot of gas with the air theoretically required for complete combustion. The values 0.029, 0.023 and 0.0189 are, respectively, the heat capacities per degree F. of CO_2, H_2O and N_2, between 60°F. and 1600°F. in Btu per cubic foot.
F = Summation of the products of the mole fractions and some constant for each combustible constituent in the gas.

Objections to "Index C" Cited

Several objections have been cited against the use of "Index C" in some cases. The formula is quite satisfactory for the usual mixtures involving the normal manufactured gases, although it does not apply for mixtures in which the percentage of inerts exceeds the free-hydrogen content. It is also applicable in the comparison of many natural gases, but it is not generally applicable for mixtures involving adjustment and substitute gases of widely differing heating value or chemical composition unless the fraction of such radically differing gas in the substitute mixture does not exceed about 12 per cent. Thus the formula does not hold for such substitute mixtures as propane or butane and air, of natural gas-inert mixtures, etc., when substituted for the usual low-Btu manufactured city-gas, but it is satisfactory if the high heating-value hydrocarbon does not exceed about 12 per cent in the final substitute mixture. The formula does not usually apply in cases involving the use of large amounts of oil gases as substitutes for natural gas. It was, in fact, found to be not fully applicable for gases of heating values higher than 800 Btu per cubic foot since the equation has no factors which predict the occurrence of yellow tips or lifting.

In 1946, the American Gas Association started a new series of tests on the interchangeability of gases of relatively low heating-value. The entire project is designated as TL-1.

To date four Research Reports have been prepared on the following:—

1106-A—*Interchangeability of Other Fuel Gases with Coke Oven Gas.*
1106-B—*Interchangeability of Other Fuel Gases with Carbureted Water Gas.*
1106-C—*Interchangeability of Other Fuel Gases with a Mixed Coke Oven—Carbureted Water Gas.*
1106-D—*Interchangeability of Carbureted Water Gases with a mixed Natural Gas—Blue Gas—Cracked Natural Gas—Producer Gas.*

Summarization of Aims, Results

The aims and results of this research by American Gas Association have been summarized in May, 1949, as follows:—

"The objective of this project is to develop a means of determining interchangeability of gas mixtures, where the base gas is in the heating-value range of 540 Btu either by—

"1. A mathematical formula which will require only a knowledge of the analysis of the mixture to determine its interchangeability, or

"2. A test burner or series of burners which will indicate the expected performance of any given mixture with customer appliance.

"The first phase of the project was a desk study to determine if it were possible to utilize the formulae previously developed by the Laboratories for the use of gases of 800 Btu or more for peak load supplements where the base load was natural gas.

"It was quickly determined that these formulae did not apply.

"The next phase was a field survey for the purpose of learning the methods used by various operating companies for determination of interchangeability. On the basis of this survey, a method of procedure was developed and necessary equipment assembled.

"The third phase of the investigation consisted of actually substituting various supplemental gas mixtures for each of 5 adjustment gases for which a number of appliances representative of those found to be most critical in the field survey were first adjusted. Some 30 supplemental gases were used in varying proportions with the adjustment gas and the performance of each appliance noted. At the same time each substitute gas mixture was tested in a number of test burners and the performance of pilot valves observed."

Interpretation of Data

"The test work has been completed and the supervising committee has worked with the Laboratories staff in attempting to interpret the data. While it has been impossible, up to the present time, to develop formulae to predict interchangeability and no single test burner has been found which can be used, there is some indication that after careful consideration of all the data some mathematical means of predicting interchangeability may be found and test burner observations may be useful. In the meantime, limiting mixtures of each supplemental gas with the five adjustment gases have been established and the data compiled in handbook form. One report has been distributed and the others will soon be available.

"The data compiled indicates those supplemental mixtures which were found by test to be satisfactory substitutes for each adjustment gas for peak load use.

"This information can be used directly wherever the composition of the adjustment gas is the same as one of the five used, or, if the gases do not differ too widely, the test data can be used as a guide using methods of approximation. A careful study of the bulletins covering this test work is recommended to all concerned with the use of a variety of supplemental gases for meeting peak loads.

"This project has emphasized the need for a study of the fundamentals of combustion. It is quite evident that our present knowledge is insufficient to permit the proper design of burners which will incorporate the flexibility necessary to satisfactorily burn the variety of gaseous mixtures we would like to use during peak load periods. Such a project is now in the formulation stage."

Very recently a statement of the American Gas Association regarding Mixed Gas research says:

"Four interim bulletins, covering the interchangeability of six base load gases with some thirty supplementary gases, have been issued and a comprehensive research bulletin has been edited by the Supervising Committee and will be available at an early date. This work while clearly establishing the limitations of existing interchangeability formulae and test burners, has as yet led to no new generalizations. Further research upon combustion fundamentals is needed. Pending such work the present bulletins will provide empirical and practical answers to the behavior of a wide variety

of mixed gases upon a selected group of highly critical appliance burners."

There are several simpler formulae which have been proposed for use in determining the interchangeability of gases.

(44) The Knoy formula is well known—

$$C = \frac{H - 175}{\sqrt{G}}$$

C = a constant
H = heating value of gas, Btu per cubic foot
G = specific gravity of gas (air = 1)
175 = the heating value in Btu per cubic foot of the primary air-gas mixture which is assumed to be the proper adjustment for domestic burners.

The theory of this formula is that gases which have the same "C" factor are interchangeable. Actually the normal flexibility of most domestic-appliance burners allows some variation in the "C" factor. This deviation will not usually exceed 10 per cent up or down from the "C" factor of the adjustment gas. "C" factor for substitute gases which are above that of the adjustment gas indicate softer types of flames, while harder flames are indicated if the "C" factor is found to be below that for the adjustment gas.

New Test Burners Devised

It is stated that the results obtained by the use of the Knoy formula may be misleading if the chemical composition of the substitute gas does not correspond to that of the adjustment gas, and as a rule, limit mixtures defined by means of A G A Index C are somewhat more reliable than those indicated by the Knoy formula.

Many test burners have been devised to assist in evaluating the interchangeability of gases by observation of flame characteristics. At the present time there is no available instrument which can be applied in all cases to evaluate the gas quality. In approaching a problem involving interchangeability of gas, it is desirable to make calculations first, using the interchangeability equations and then burn the prepared mixtures in appliances having burners characteristic of those used in the community to be certain that the substitute gases will actually burn satisfactorily.

It is desirable that gas companies keep a control burner at the inlet and outlet of their gas-storage holders in order that they may, at all times, have a knowledge of the burning characteristics of the gas being produced and sent out.

Having considered the possibilities of using substitute gases for some normal send-out gas, it is apparent that no general statement can be made that any gas will or will not satisfactorily replace another gas. It is necessary that each situation be studied carefully, using the equations given here together with operation of test appliances.

High Btu Oil Gas Not Complete Replacement

It can be stated that high Btu oil gas, as now known, cannot be used as complete replacement for natural gas. However, some 30 to 60 per cent of these high Btu oil gases can be used in admixture with natural gas without excessive complaints from the consumers of the gas.

It must be pointed out that in some cases substitute gases appear to be entirely satisfactory from the standpoint of visual flame characteristics, but the products of combustion may contain dangerous quantities of carbon monoxide.

It should be possible to supply an equation based solely on the chemical analysis of the gases which could be used for determining the interchangeability of gases. The Laboratories of the American Gas Association have done considerable work on this problem and may be able to supply such an equation in the near future. In the meantime, it is necessary to use the equations so far developed and consider each case separately.

Storage of Gases or Mixtures of Gases Considering Deviations from Ideal Gas Laws

STORAGE cylinders, operating at relatively high pressures, are capable of offering increased storage capacity, considering the effect of deviation from the ideal gas law, to the extent of approximately 40 per cent over underground storage sands.

In the case of mixtures of gases, such as natural gas, deviation from the ideal gas law is dependent on the composition of the mixture. A method of determining this deviation for a gas of any composition and of calculating the increase in volumetric capacity under optimum operating conditions is presented.

In the compression of a gas, when the working pressure exceeds approximately 50 psi gage, there is a difference between the actual volume and the volume expected as determined by the ideal gas law,

$$PV = NR'T \qquad (1)$$

where

P = pressure in pounds per square inch absolute

V = volume in cubic feet

N = number of pound-moles of gas = $\frac{\text{Weight of gas in pounds}}{\text{molecular weight}}$

R′ = universal gas constant = 10.71 for cubic foot and pounds per square inch

T = temperature, absolute = 460 + °F

The difference is generally a shrinkage accompanied by a corresponding increase in density. This shrinkage, or deviation, is a function of both pressure and temperature, and reaches a maximum at the critical pressure and temperature of the gas.

Since the ideal gas law (Equation 1) has been used in the derivation of nearly all equations of state, the most convenient method for determining the pressure, volume, temperature relationships of a gas or gaseous mixture is to introduce into Equation 1 a compressibility factor Z which represents the deviation of the gas in question from the ideal gas laws and may be expressed as follows:

$$PV = ZNR'T \qquad (2)$$

where

Z = compressibility factor

Actually, the compressibility factor Z is a dimensionless correction factor dependent on the character of the gas, the temperature, and the pressure. Values of Z have been experimentally determined[1][2]*, and were found to be a function of reduced pressure and reduced temperature, and have been plotted accordingly in Fig. 1.

The compressibility factor Z, or the deviation of a gas or a gas mixture from the ideal gas laws, is expressed in terms of reduced pressure P_r (ratio of the actual absolute pressure to the critical pressure) and of reduced temperature T_r (ratio of the actual temperature to the critical temperature), the relationship being expressed as follows:

$$P_r = P/P_c \qquad (3)$$

$$T_r = T/T_c \qquad (4)$$

where

P = pressure in pounds per square inch absolute

T = temperature, absolute = 460 + °F

P_c = critical pressure of gas or gas mixture

T_c = critical temperature of gas or gas mixture

The critical pressure of a gas is the pressure under which the gas may exist in a gaseous state in equilibrium with its liquid at the critical temperature. The critical temperature is the temperature above which a gas cannot be liquefied by pressure alone. Values of critical constants may be obtained from critical tables and handbooks, or reference may be made to Table I wherein are listed properties of constituent gases.

(Continued on page 145)

* See page 147 for bibliography.

TABLE 1—PROPERTIES OF GASES.

Gas	Formula	Molecular weight	Boiling point at atmosphere °F	Specific gravity Air = 1.00	Critical temperature °F abs.	Critical pressure psi abs.
Methane	CH_4	16.03	−259	0.553	344	673
Ethane	C_2H_6	30.05	−127	1.037	549	712
Propane	C_3H_8	44.06	− 44	1.521	666	632
Isobutane	C_4H_{10}	58.08	10	2.005	732	544
Isopentane	C_5H_{12}	72.09	82	2.488	829	482
Carbon dioxide	CO_2	44.00	−109	1.520	548	1073
Nitrogen	N_2	28.02	−320	0.970	227	492
Oxygen	O_2	32.00	−297	1.105	278	730

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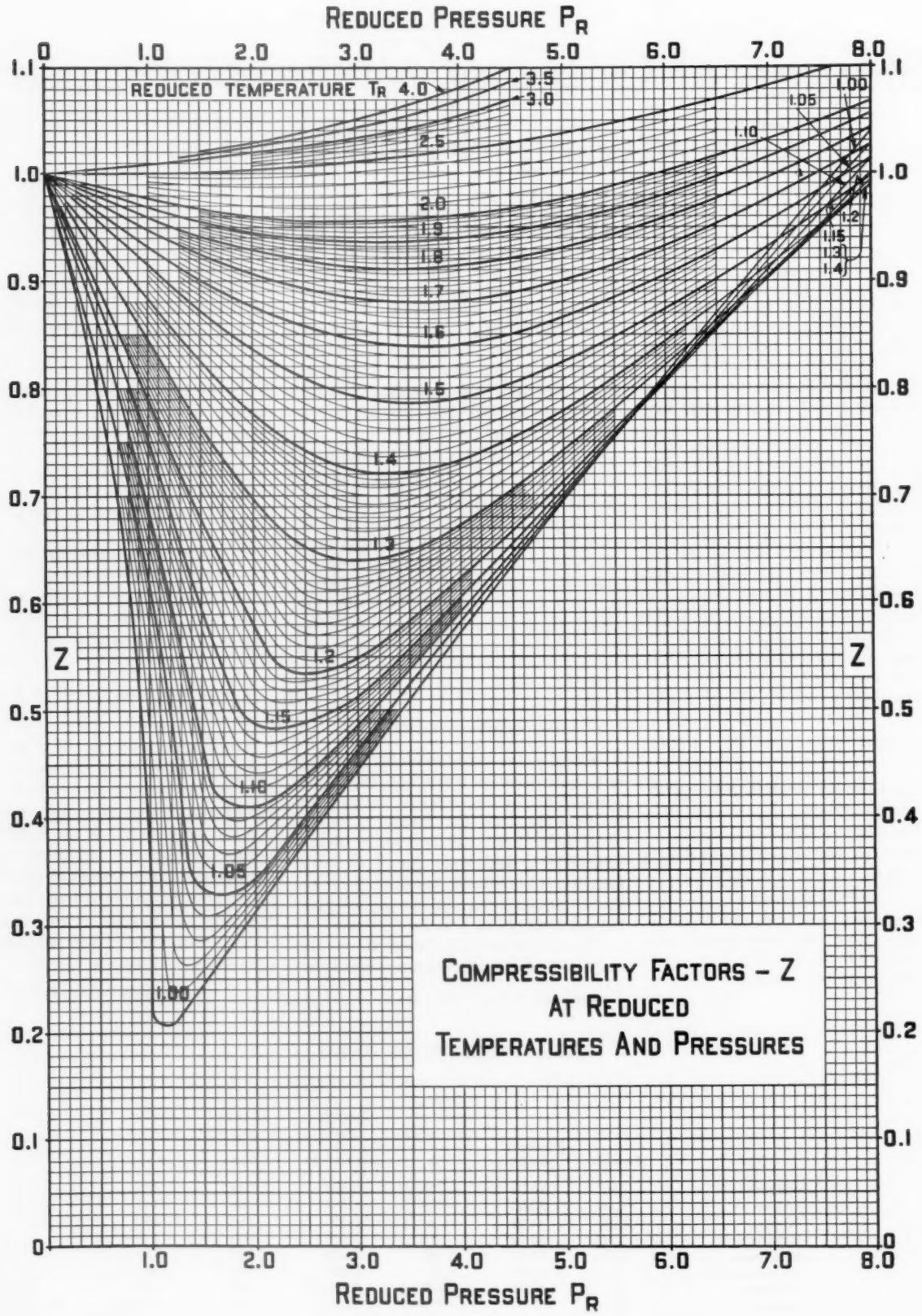

Fig. 1

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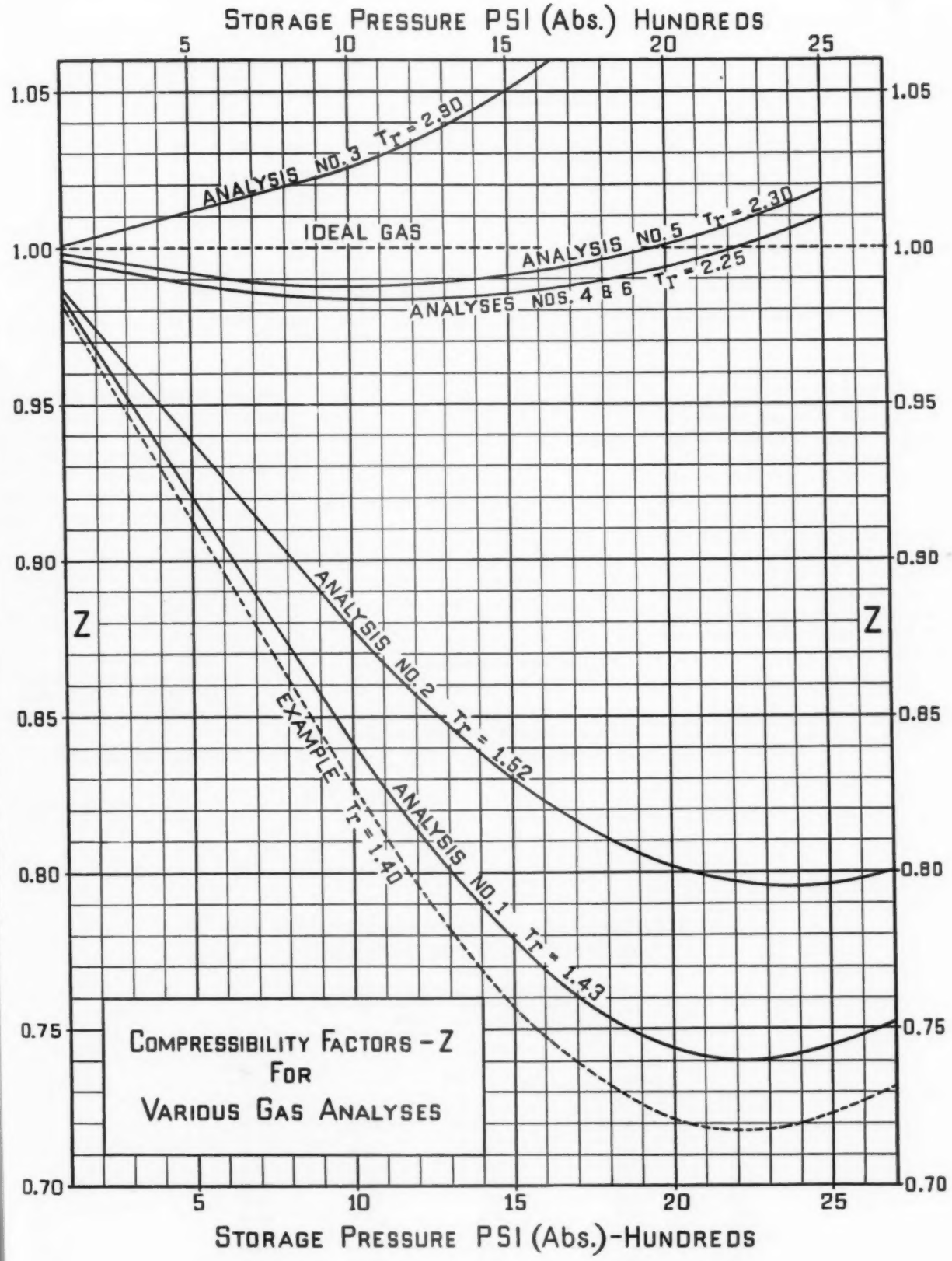
STORAGE PRESSURE PSI (Abs.) HUNDREDS
5
10
15
20
25
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
Z
ANALYSIS NO. 3 Tr = 2.90
IDEAL GAS
ANALYSIS NO. 5 Tr = 2.30
ANALYSES NOS. 4 & 6 Tr = 2.25
ANALYSIS NO. 2 Tr = 1.52
EXAMPLE Tr = 1.40
ANALYSIS NO. 1 Tr = 1.43
COMPRESSIBILITY FACTORS – Z
FOR
VARIOUS GAS ANALYSES
STORAGE PRESSURE PSI (Abs.)-HUNDREDS

Fig. 2

TABLE 2—VARIOUS GAS ANALYSES.

Component	Formula	Example	Natural gas		Coke-oven gas	Producer gas: Pittsburgh coal Best	Producer gas: Pittsburgh coal Average	Producer gas: Illinois coal
Analysis number			1	2	3	4	5	6
Methane	CH_4	84.8	84.5	94.5	29.7	3.4	2.3	2.5
Ethane	C_2H_6	14.3	11.5	0.5	1.1	....	....	....
Carbon monoxide	CO	....	....	....	5.9	27.5	24.7	25.4
Hydrogen	H_2	....	....	....	57.0	12.7	15.0	11.0
Oxygen	O_2	0.2	....	0.3	....	0.2	0.2	0.1
Nitrogen	N_2	0.6	3.8	4.0	0.7	50.8	52.2	54.0
Carbon dioxide	CO_2	0.2	0.2	0.2	0.7	4.6	4.8	5.2
Ethylene	C_2H_4	....	....	0.5	3.4	0.8	0.8	0.6
Critical pressure, psi abs.	P_c	678.1	672.0	667.3	381.6	494.8	486.4	494.8
Critical temperature, °F abs.	T_c	372.6	363.7	341.4	179.5	231.0	226.1	231.1
Reduced temperature	T_r	1.40	1.43	1.52	2.90	2.25	2.30	2.25

(Continued from page 142)

In a gaseous mixture consisting of numerous component gases, the compressibility factor is determined by having recourse to the so-called pseudo-critical values of the mixture. The pseudo-critical pressure is the molecular average critical pressure of the gas mixture and the pseudo-critical temperature is the molecular average critical temperature of the mixture. The relationship to the critical pressure and temperature of the fundamental gases may be expressed as follows:

$$P_c = (P_c)_a N_a + (P_c)_b N_b + \quad (5)$$

$$T_c = (T_c)_a N_a + (T_c)_b N_b + \quad (6)$$

where

N_a = Gas (a) of gas mixture as a volume fraction

N_b = Gas (b) of gas mixture as a volume fraction

P_c = Pseudo-critical pressure of gas mixture

$(P_c)_a$ = Critical pressure of N_a

$(P_c)_b$ = Critical pressure of N_b

T_c = Pseudo-critical temperature of gas mixture

$(T_c)_a$ = Critical temperature of N_a

$(T_c)_b$ = Critical temperature of N_b

In order to illustrate the determination of the compressibility factor, the following example is cited:

Example—Gas analysis, per cent by volume: Methane, 84.81; Ethane, 14.26; Nitrogen, 0.63; Carbon Dioxide, 0.15; Oxygen, 0.15. Required, the deviation for 2000 psi absolute and 60° F. The pseudo-critical pressure and temperature must be determined by means of Equations (5) and (6) and Table I.

$$P_c = (P_c)_a N_a + (P_c)_b N_b + \quad (5)$$

$$P_c = 673(0.8481) + 712(0.1426) + 492(0.0063) + 1073(0.0015) + 730(0.0015) = 678.1 \text{ psi absolute}$$

$$T_c = (T_c)_a N_a + (T_c)_b N_b + \quad (6)$$

$$T_c = 344(0.8481) + 549(0.1426) + 227(0.0063) + 548(0.0015) + 278(0.0015) = 372.6° \text{ F absolute}$$

(Continued on page 147)

TABLE 3—DETERMINATION OF COMPRESSIBILITY FACTOR AND ATMOSPHERIC VOLUMETRIC MULTIPLIER.

Given: Critical Pressure = 678.1 psi abs.
Critical Temperature = 372.6° F abs.
Reduced Temperature = 1.396

Storage pressure P_p	Reduced pressure $P_r = \frac{P_p}{678.1}$	From Fig. 1 Z_p For $T_r = 1.396$ For $P_r = \frac{P_p}{678.1}$	$14.73Z_p$	Atmospheric volumetric multiplier $\frac{P_p}{14.73Z_p}$
100	.147	.983	14.48	6.91
250	.369	.955	14.07	17.77
500	.737	.912	13.43	37.23
750	1.106	.871	12.83	58.46
1000	1.475	.828	12.20	81.97
1250	1.843	.790	11.64	107.39
1500	2.212	.756	11.14	134.65
1750	2.581	.736	10.84	161.44
2000	2.949	.721	10.62	188.32
2250	3.318	.718	10.58	212.67
2500	3.687	.722	10.64	234.96
2750	4.055	.733	10.80	254.63
3000	4.424	.748	11.02	272.23

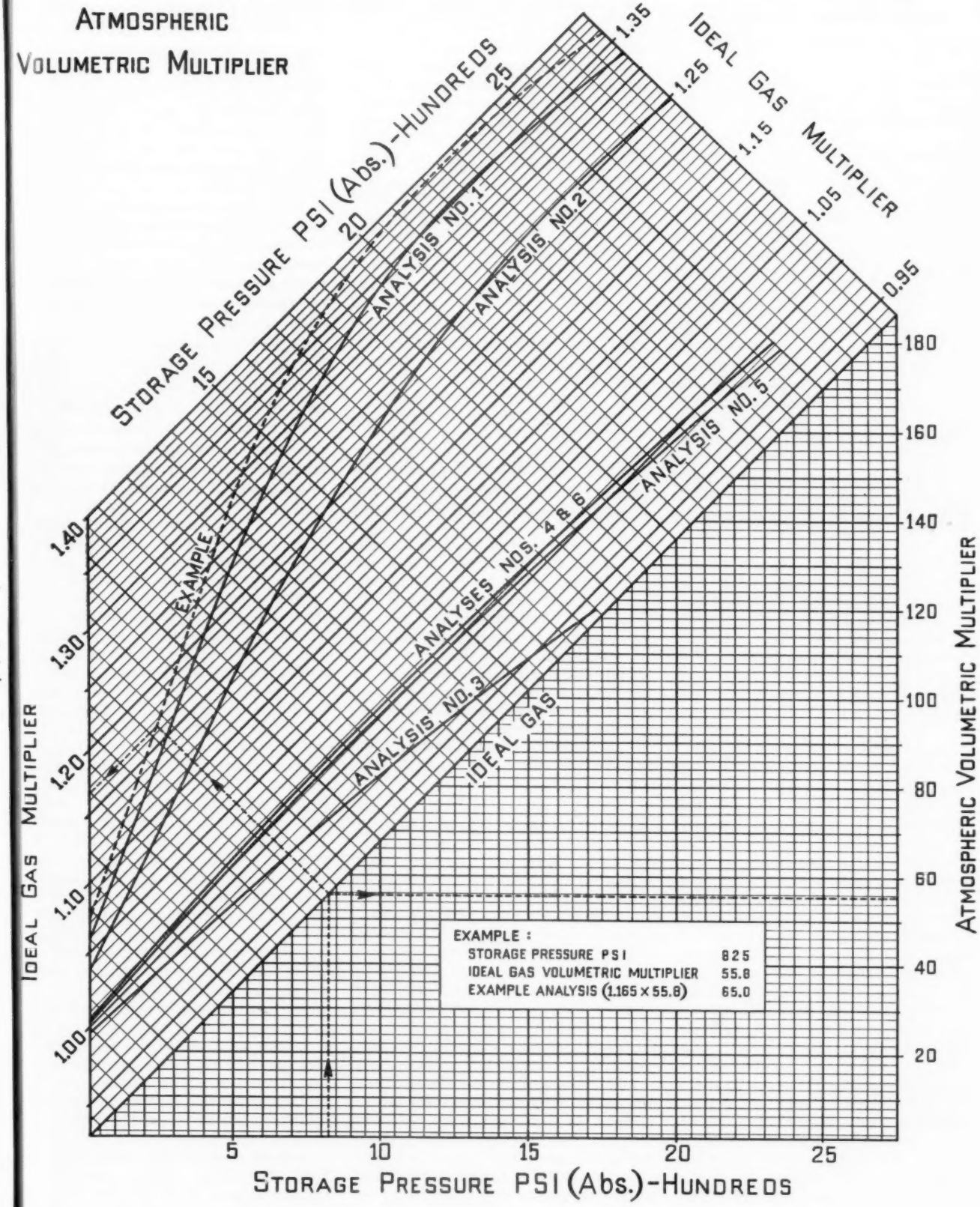
ATMOSPHERIC
VOLUMETRIC MULTIPLIER
STORAGE PRESSURE PSI (Abs.)-HUNDREDS
IDEAL GAS MULTIPLIER
ANALYSIS NO. 1
ANALYSIS NO. 2
ANALYSIS NO. 5
ANALYSES NOS. 4 & 6
ANALYSIS NO. 3
IDEAL GAS
EXAMPLE
EXAMPLE :
STORAGE PRESSURE PSI 825
IDEAL GAS VOLUMETRIC MULTIPLIER 55.8
EXAMPLE ANALYSIS (1.165 x 55.8) 65.0
IDEAL GAS MULTIPLIER
ATMOSPHERIC VOLUMETRIC MULTIPLIER
STORAGE PRESSURE PSI (Abs.)-HUNDREDS

Fig. 3

(Continued from page 136)

Reduced pressure and reduced temperature are determined from Equations (3) and (4).

$$P_r = P/P_c \qquad (3)$$

$$P_r = \frac{2000}{678.1} = 2.949$$

$$T_r = T/T_c \qquad (4)$$

$$T_r = \frac{60 + 460}{372.6} = 1.396$$

From Fig. 1, for $T_r = 1.396$ and $P_r = 2.949$, we find the compressibility factor $Z = 0.722$. It should be noted that if in the preceding example the gas had been at atmospheric pressure, the compressibility factor would approximate unity.

For comparative purposes Fig. 2 has been prepared based on the seven gas analyses of Table II giving the compressibility factor Z as a function of storage pressure and reduced temperature. Similarly, for any other gas analyses plots could be made to indicate the optimum pressure-deviation relationship. In this manner the designer of storage cylinders will be able to determine the magnitude of the increase in the storage capacity under optimum conditions. In the case of gas analysis No. 1, the best operating pressure would be 2250 psi absolute, the compressibility factor being .740.

If under standard conditions of pressure and temperature the volumetric content of a cylinder is known, the magnitude of the increase in storage capacity may be predicted based on the deviation from the ideal gas laws and the storage pressure.

$P_aV_a = Z_aNR'T$ and $P_pV_p = Z_pNR'T$ where subscripts a and p represent values at standard or atmospheric conditions and under pressure, then

$$V_a = \frac{Z_aP_p}{Z_pP_a}\ V_p \qquad (7)$$

but Z_a = unity at standard conditions and P_a = 14.73 psi. When substituted in Equation (7) the expression in terms of standard volume will be

$$V_a = \frac{P_p}{14.73Z_p}\ V_p \qquad (8)$$

Therefore, the expression $\frac{P_p}{14.73Z_p}$ represents a volumetric multiplier and, knowing the volume under standard conditions, the volume of gas that can be stored under operating conditions may be anticipated by multiplying the known volume by this calculated value.

Atmospheric volumetric multipliers for the seven gas analyses of Table II have been determined and are shown in Fig. 3, and, similarly, for any other gas analysis a plot may be established to show the expected volumetric increase for each analysis.

To further illustrate, using the gas analysis of the previous example, Table III shows the required calculations for the determination of the compressibility factor Z and the volumetric multiplier k for a storage pressure range of 100 psi to 3000 psi absolute.

In the foregoing discussion the probabilities of hydrate formation or liquefaction of the gas have not been taken into consideration. For any specific gas mixture these critical points should be determined for the anticipated operation conditions before proceeding with the investigation of optimum conditions of storage.

BIBLIOGRAPHY

(1) Deviation of Natural Gas From Ideal Gas Laws
By George Granger Brown
University of Michigan

(2) Chemical Engineers' Handbook
By John H. Perry
McGraw-Hill Book Company, New York

Methods of Controlling Corrosion

THE control of corrosion can be accomplished by one or more of several general methods such as: selection of right-of-way to avoid obvious corrosive spots; coating the pipe with some kind of protective film or wrapper; or by forcing current to flow onto the pipe either through its entire length or at least within those areas at which current would otherwise be flowing off of the pipe due to the presence of natural galvanic cells or to the pipe being within the positive area of stray earth currents. This latter means of protection can be accomplished in two general ways, that is, by creating a galvanic cell directly opposed to the natural galvanic cell of the pipe line, or by impressing electric current from an outside source directly on the pipe line.

Ordinarily the right-of-way for a line is chosen to approximate a straight line between two points and at the same time permit ease of construction and maintenance of the pipe line. A soil survey conducted along the proposed course of a pipe line sometimes indicates small corrosive areas which can be avoided without increasing either the installation cost of the line or its accessibility for maintenance. This, of course, is the first step in the control of corrosion.

The second general method for preventing corrosion is to completely cover the surface of the buried pipe with some kind of a protective coating.

All of the three general types of corrosion involve a flow of electric current. The extent of the corrosion depends upon the magnitude of these electric currents. It becomes obvious therefore that if we can maintain some type of electric insulating material as a barrier between the pipe and ground it would be possible to stop the flow of these electrical currents and thereby prevent the corrosion.

There are many different kinds and of coating materials, such as as- coal tars, plastics, mastics, greases ncrete, and although it is not an insulating material, the metallic coating, such as galvanizing. A coating which is perfectly satisfactory on one pipe line for one location may or may not be satisfactory on another pipe line at a different location because the soil conditions and environment at one location are entirely different from those at another.

Metallic coatings (galvanized pipe) are not well adapted to underground use because of the galvanic action between the metallic coating and the dissimilar nearby metals. These metallic coatings are often used to considerable advantage to prevent atmospheric corrosion.

THIS ARTICLE on corrosion control and the one on cathodic protection, next page, have been adapted, with permission, from "A Manual on Underground Corrosion," a copyrighted book prepared by the Columbia Gas System Service Corporation, a subsidiary of Columbia Gas System.

Concrete coatings were at one time very popular and extensively used to combat corrosion. Their cost is relatively high, and since they have a tendency to absorb moisture, check and crack, they are not now extensively used. There are actual instances of locations where the use of concrete coatings has accelerated pipe corrosion.

The grease coatings are made from a petroleum base with a paraffin or wax-like texture, and may be applied either hot or cold depending upon the specification of the particular grease coating. Both the hot and cold greases must be shielded from the surrounding earth by a wrapper, since the soil backfill tends to damage the grease coating. In addition to this displacement of coating, the soil tends to absorb some of the materials in this type of coating.

Most mastics are considered to be good coatings. These coatings are composed of aggregates such as sand, gravel, asbestos, or clay, bonded with either coal tar, asphalt, or one of the newer plastics. They may be either hot or cold applications depending upon the specification of the material used. They are generally applied as a thick coating, sometimes as much as ⅜ to ¾ of an inch in thickness. These mastic coatings are relatively expensive and consequently are not often used except for highly corrosive soil conditions.

Plastic coatings are among the newcomers in pipe line protective coating materials. Most of them are still in the early stages of development and have not yet been tested by actual industrial application. Preliminary tests indicate that some of these may be highly desirable pipe protective materials. But definite statements concerning their relative qualifications are not now possible.

The coal tar and asphalt coatings are by far the most popular of the coating materials used to prevent corrosion. Of these two bituminous coatings, asphalt and coal tar, asphalt as a basic material for protection ranks among the oldest known to man. The Egyptians made extensive use of asphalt as a water proofing and protective material in the construction of their boats. Natural asphalt was also used as a protection against water in the construction of tombs and mummy cases. Down through the ages, constant references are made to natural asphalt as a protective coating.

Asphalt base coating materials whether from a natural source or as a petroleum refining residue are extensively used today as pipe coating material. In general, they are less susceptible to impact and temperature changes than the coal tar base enamels, but they may be affected by the absorption of small quantities of soil moisture or they may be dissolved by oil products contained in the soil.

Coal tar base coatings are probably the most widely used pipe line coating materials of the present day. This is because they can be combined in many different ways to meet the many different requirements of pipe line construction. Their permanence, continuity, hardness, adhesion and corrosion resistance, combined with their relatively low cost, make them more desirable as a pipe line protective coating material.

Both coal tar base coatings and asphalt base coatings are manufactured to meet different specifications such as softening point, weight per gallon, coefficient of expansion, etc., so that the most appropriate protection can be selected for any particular job of coating. They are generally applied to provide approximately 3/32 of an inch of coating thickness.

One of the most important steps for the application of either of these coatings is the proper preparation of the pipe to be coated. The pipe must be clean, free of dirt, moisture, rust, mill scale and the like, and must be primed by painting with some material which will bond to the pipe and to the material with which it is proposed to protect the pipe. In most cases, with hot coatings at least, it is customary to wrap over the enamel or coating while it is still hot and viscous with a felt, asbestos, or glass fiber wrapper. The purpose of the wrapper is to prevent injury to the coating during backfill and deformation of the coating due to soil stresses produced as the backfill settles.

Sometimes combinations of wrappers are used. An excellent combination consisting of a fiber glass wrapper imbedded in the enamel supplemented by an asbestos felt wrapper bonded to the surface of the enamel. The glass wrapper reinforces the coating and the asbestos felt wrapper protects it from soil stress.

Sometimes these coatings are applied by hand and sometimes by the use of the machinery. Small coating jobs including the patching of large machine applied

jobs are usually accomplished by hand using a canvas sling and pouring bucket to apply the coating material. Coating jobs which are not large enough to warrant the use of over-the-ditch machinery may be completed by using a rolling rig either along the right-of-way or in the pipe yard or rail terminal.

Inspectors usually watch the application of the coating and wrapper to see that they are applied according to the specifications. In addition to this visual inspection of the application of the coating, most applied coatings are checked to determine whether or not there are any small faults or pinholes commonly called "holidays" in the coating. This is usually accomplished by using one of several different kinds of electrical testing devices or "holiday" detectors.

All of these tests are done before the pipe is lowered in the ditch. During the course of lowering and backfilling, additional holidays may be formed. These can be detected by means of a special electrical device even though the pipe is buried. If this special instrument indicates any large areas where the coating has been damaged, it may be necessary to uncover the line to repair the damaged place. If the instrument indicates that the area is very small, then other means of protection may be utilized.

Cathodic Protection

ALTHOUGH this method of protection is rather simple in principle, its application can become complicated, particularly if there are other underground structures in the same area. The actual method of distributing the "impressed current" along the pipe line can be accomplished by many different methods. Typical wiring diagrams for some of these methods are shown in Figures 1, 2 and 3.

Figure 1. Cathodic Protection: Single Rectifier and Ground Bed (Anode).

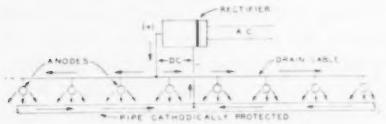

Figure 2. Cathodic Protection: Rectifier and Distributed Ground Bed or Anodes.

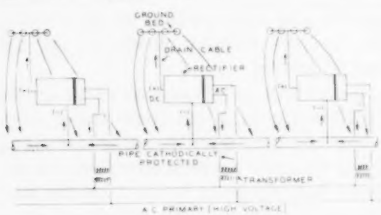

Figure 3. Cathodic Protection: Distributed Rectifiers with Single Ground Beds.

This system of protection is also susceptible to complications because of what is called "cathodic interference" (Figure 4). Suppose, for example, there is a high pressure line going through that portion of a distribution system which it is desired to protect by means of "impressed current." This high pressure line may also pick up current from the ground and carry it along to some place where the high pressure line crosses over or goes near the distribution line. Then because the current has to get back to the power source, it will jump from the high pressure line to the ground to the distribution line. This short section of the high pressure line becomes an anode.

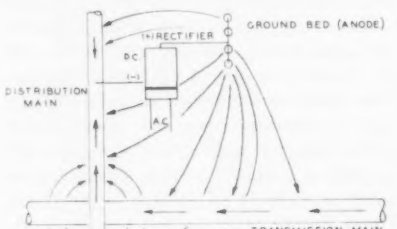

Fig. 4. Cathodic Interference.

Every ampere of current leaving the pipe in this area is going to carry pipe wall metal with it, 20 pounds per ampere per year, and a leak on the high pressure line could be guaranteed.

The same sort of cathodic interference may be caused by reason of some other company installing "impressed current" protection for their system of cables or pipe lines as illustrated in Figure 5. In this case, the rails of an abandoned street car system are being used as the ground bed is collected by the other underground structures (Pipeline A and Pipeline B). The stray currents that have collected on these pipe lines must return to the cathodic protection unit, therefore, there will of necessity be an area somewhere along these pipe lines where this current is flowing from the pipe line to the ground. In other words, the lines have become anodes, and it is the anode which corrodes.

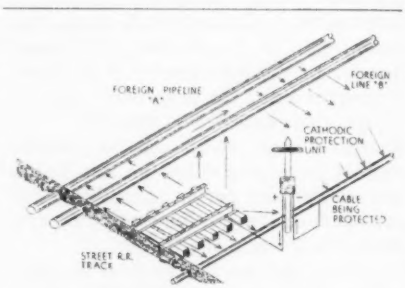

Figure 5. Stray Current Corrosion.

It sometimes requires a very elaborate wiring system to effectively equalize the various underground structures which may be exposed to stray currents by the use of cathodic protection units. In practice, the use of "impressed current" to protect a network of lines becomes so complicated that its application should only be undertaken by the experienced Electrolysis and Corrosion Engineer.

We have proved by experience that a copper service line can be protected by reason of its being the cathode of a dissimilar metal galvanic cell. It follows quite logically that if it were possible to make all of the area along a pipe line the cathode of a strong galvanic cell by using an expendable dissimilar metal, it would be possible to suppress the natural anode areas along the pipe, and thus keep them from developing pit holes. There are three readily available metals, aluminum, zinc, and magnesium, each of which will form reasonably strong galvanic cells when combined with iron. Any one of the three can be used to construct this galvanic cell. Magnesium forms the strongest cell of the three and is therefore most often used (Figure 6).

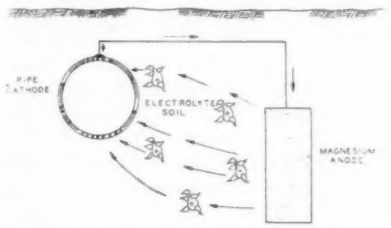

Figure 6. Cathodic Protection: Galvanic Anodes.

This expendable anode galvanic cell as used for pipe protection is similar to a flashlight battery. The magnesium ingot is the expendable anode; the soil is the electrolyte; the pipe surface the center cathode; and the insulated wire, with one end soldered to the pipe and the other to the magnesium, completes the electrical circuit. Current will flow from the magnesium to the ground, taking metal ions of magnesium with it. It then flows through the ground onto the pipe, counteracting the undesirable natural galvanic cells that may be encountered back to the magnesium anode through the connecting wire.

The ingots of magnesium used to create these galvanic cells may be any one of a number of different sizes and weights. The sizes ordinarily used are 4#, 8#, 12#, 16#, and 32#. Their physical dimensions are varied, depending upon who manufactured the ingots. Some of these ingots are cylinders from 4" to 8" in diameter. Others are square in cross section and are from 2" to 6" on a side.

Still another type of magnesium anode is in the form of a ribbon about ⅜" x ¾" with a solid iron wire as a core. This ribbon can be obtained in 2,000' spools and weighs about a quarter of a pound per foot.

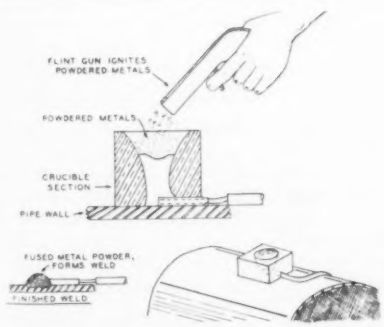

Figure 7. Thermit Weld Process.

Except for the ribbon type anodes, the magnesium is usually installed by digging a hole deep enough to put the ingot of magnesium about on a level with the pipe line, filling in around the magnesium with some sort of special "backfill." The purpose of the "backfill" is to provide better electrical efficiency for the magnesium. There are many specially prepared backfills for this purpose, but field tests have demonstrated that ordinary builders plaster mixed with sand is just as satisfactory as the most expensive special backfill. An insulated copper wire is used to connect the iron core of the magnesium anode to the surface of the pipe. Connections to the pipe are ordinarily made by using a thermit welding cup to fuse the wire to the pipe metal (Figure 7). This welded joint must then be covered with an insulating material such as pipe coating to keep it from creating an additional and undesirable galvanic cell.

There are many possible combinations for connecting anodes to the pipe line. The size of anode, the number, their distance apart, the distance from the pipe line, and the like, are all functions of the use to be made of the anode. A number of anodes spaced from 5 to 50' apart along the right-of-way may be attached to a single wire running parallel to the pipe line. This wire in turn will be connected to the pipe line at about 500' intervals. In other cases individual anodes are directly connected by wire to the pipe line and these anodes will be whatever distance apart required to insure that some current, small amount though it may be, is flowing onto every square foot of the pipe line it is proposed to protect.

Figures 8 and 9 show typical installations of these combinations.

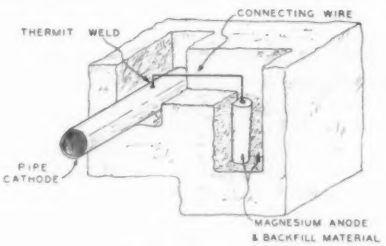

Figure 8. Cathodic Protection: Single Anode Installation.

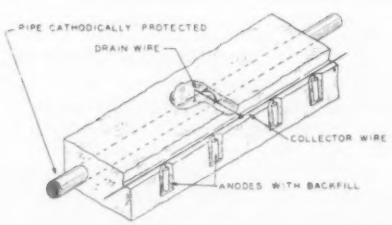

Figure 9. Cathodic Protection: Multiple Anodes in Series Installation.

When the ribbon type magnesium anode is used, it is plowed under the surface of the ground and runs parallel to the pipe line. The pipe and ribbon are connected by insulated wire at intervals along the length of the installation. This continuous ribbon type anode is plowed in by using a conventional cable laying plow (Figure 10).

The number of locations at which it is possible to use this continuous ribbon is limited by the fact that ⅜" x ¾" ribbon weighing about a quarter of a pound per foot does not provide a very large mass of magnesium at any one place along the pipe line. Therefore, it cannot be used where relatively large amounts of current will flow onto the line. For the most part, installations of ribbon may be used in soils having a relatively high resistance to the flow of electricity, for ordinary installations on small diameter pipe, or where it is only desired to protect the line for a short period, say five to ten years.

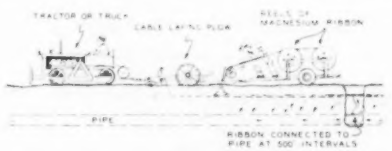

Figure 10. Cathodic Protection: Magnesium Ribbon Installation.

Most installations of magnesium are designed so that the magnesium anodes will provide a small amount of current flowing onto each square foot of the pipe line and still have sufficient mass of magnesium to last at least 25 years.

The magnesium anode will corrode to provide this protection, and enough must be installed so that the amount of magnesium present is sufficient to provide metal to corrode for the period over which it is proposed to protect the pipe line.

The type of anode installation to be made is a matter of choice to the corrosion engineer. The installation he selects will depend upon a number of factors such as the size of the pipe line, the number and activity of the galvanic cells existing along the pipe line, whether or not the soil offers very much resistance to the flow of electricity, and of course, how many years of life it is desired to add to the unprotected normal life of the line.

When magnesium anodes are installed in connection with the regular maintenance and repair program of the pipe line, there is no necessity for having a "profile" or other special tests. Any time it becomes necessary to replace a short piece of line, two or three anodes or one anode for each 20' joint can be installed at the same time in the same ditch with the pipe (Figure 11).

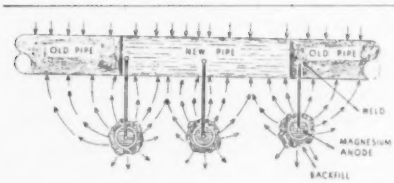

Figure 11. Cathodic Protection: Magnesium Anodes to Protect Old and New Pipeline.

Once the field crews have been shown how to make the installation, they can continue by themselves. There is no need for a corrosion engineer to be on hand for each individual job.

If some particular spot along the pipe line is developing pit hole leaks, then a single 8" magnesium anode can be installed at the time the pit hole saddle is attached (Figure 12). Once again, the field crews repairing the leak can make the installation of the anode.

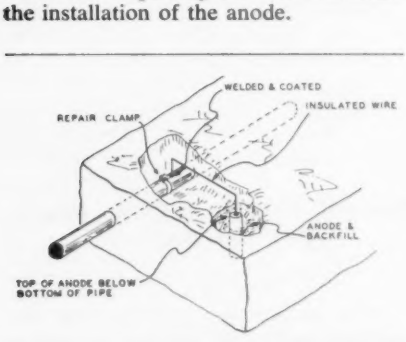

Figure 12. Cathodic Protection: Single Anode Installation in Leak Repair Bell Hole.

With expendable anode installations the deliberate use of an insulated joint may become a very desirable feature. By properly isolating various sections of the line, one from the other, it is often possible to protect the line against corrosion without affecting other sections not requiring protection, and perhaps even make it possible to use fewer anodes to secure the desired protection. This is particularly true on distribution systems. Figures 13 and 14 show typical installations of magnesium anodes on distribution mains and services that are electrically insulated from other structures.

Expendable magnesium anodes can be extremely valuable to prevent the corrosion of coated pipe on both transmission and distribution piping but particularly on distribution systems. Figure 15 shows the cross section at a pipe wall of an insulated line having two small defects in the coating, called "holidays." Any galvanic currents flowing in the pipe line will be concentrated at these places where there is no barrier to the flow of the current from the pipe to the ground, with the result that extreme and rapid pitting may occur. By installing a magnesium anode and connecting it to the coated pipe (Figure 16), it is possible to prevent the flow of current from the pipe to soil at these holidays, and instead, force current to flow from the magnesium anode to the ground, through the hole in the coating onto the pipe line, returning to the magnesium anode through the insulated wire. The magnesium anode will corrode instead of the pipe.

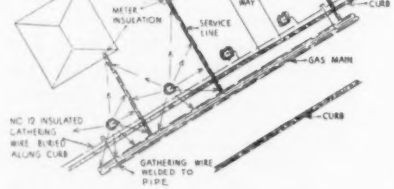

Figure 13. Cathodic Protection: Anode Installation on Distribution Piping.

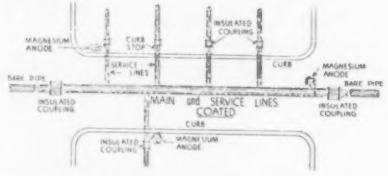

Figure 14. Cathodic Protection: Anode Installation on Coated Distribution Systems of Gas Pipeline.

Figure 15. Concentration of Corrosion at Breaks and Pin Holes in Coating.

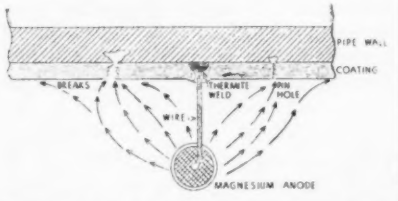

Figure 16. Pipe Protection with Coating and Anodes.

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Gas as a raw product

CHEMICALS FROM NATURAL GAS—J. J. Hogan—SGA.

USES OF NATURAL GAS AS A RAW MATERIAL—G. R. Walton—SGA.

Gas codes

EXPERIENCES IN OPERATING UNDER A GAS CODE—Frank E. Hodgdon, Dwight M. Baker and R. M. Curry—SGA.

REPORT ON ASA CODE B31, CODE FOR PRESSURE PIPING—Frank S. G. Williams—AGA.

WISCONSIN GAS SAFETY CODE DEVELOPMENTS—Vance Uhlmeyer, G. G. Ellerbrock—WUA.

Gas conditioning

APPLIANCE SERVICING AS AFFECTED BY VARYING GAS CONDITIONS—W. C. Peters—AGA.

DETERMINATION OF WATER VAPOR IN NATURAL GAS BY A DIRECT CHEMICAL METHOD—W. F. Brickell—AGA.

GLYCOL DEHYDRATION PLANT CORROSION AND FOULING—H. O. Kruger—PCGA.

IMPROVEMENT OF CATALYSTS AND CATALYST SUPPORTS—H. A. Dirksen, C. H. Riesz, and W. J. Pleticka—AGA.

INFLUENCE OF SUBSTITUTE GAS COMPOSITION ON INTERCHANGEABILITY WITH NATURAL GAS—D. L. Nicol, H. R. Linden and R. A. Brown—AGA.

MAIN CONDITIONING FOR LEAK CONTROL, CLEANING MAINS AND DUST FILTERS—Thomas J. Lambeck and R. K. Levey—WUA.

OIL FOGGING EQUIPMENT AND OPERATION AT BALTIMORE—O. W. Lusby—AGA.

PREVENTION OF POLLUTION BY OIL—Charles Koons—AGA.

SULPHUR POISONING OF NICKEL CATALYSTS—Research Bulletin #10, AGA.

U.G.I. CYCLIC CATALYTIC REFORMING PROCESS, RECENT DEVELOPMENTS—E. H. Smoker—AGA.

USE OF DIETHYLENE GLYCOL IN LINE DUST SCRUBBERS—D. W. Ansell—PCGA.

Gas flow

COMPUTATION OF FLOW CONDITIONS IN GAS PIPELINES BY THE McILROY FLOW NETWORK ANALYZER—C. L. Barker—PCGA.

GAS PIPE NETWORKS ANALYZED BY DIRECT-READING ELECTRIC ANALOGUE COMPUTOR—AGA.

SOLUTION TO CONTROL AND MEASUREMENT OF A WIDELY FLUCTUATING INDUSTRIAL PROCESS LOAD—W. C. Cameron—PCGA.

High Btu gases

EFFECTS OF SCRUBBING HIGH BTU GASES—John Scholar—AGA.

PROBLEMS ENCOUNTERED IN THE OPERATION OF A STANDBY HIGH BTU OIL GAS PLANT—Glenn M. Hammond—AGA.

SELECTION OF OILS FOR HIGH-BTU OIL GAS—Research Bulletin #12, AGA.

Hydrostatic testing

HYDROSTATIC TEST OF A 22" TRANSMISSION LINE—W. L. Masheter—PCGA.

PIGS IN HYDROSTATIC TESTS ON LARGE DIAMETER PIPELINES—M. J. Binckley—PCGA.

Incinerators

INSTALLATION AND VENTING OF GAS FIRED INCINERATORS—J. G. Dierkes—M-WGA.

Industrial load

CURRENT DEVELOPMENTS IN GAS-OPERATED POWER SOURCES FOR INDUSTRIAL APPLICATIONS—E. L. Miller—SGA.

EFFECT OF NATURAL GAS ON PRODUCTION PLANT OPERATION—J. W. Carroll—AGA.

KEEPING GAS UTILIZATION IN STEP WITH PRODUCT AND PROCESS—Jack Huebler—AGA.

SOLUTION TO CONTROL AND MEASUREMENT OF A WIDELY FLUCTUATING INDUSTRIAL PROCESS LOAD—W. C. Cameron—PCGA.

Instruments

A FORMALIZED TRAINING PROGRAM FOR INSTRUMENT REPAIRMEN—R. W. Few—PCGA.

Leakage

APPROACH OF A SMALL COMPANY TO THE GAS LEAKAGE PROBLEM—L. K. Mundth—PCGA.

LEAKAGE CONTROL—Davis Watkins—PCGA.

LEAKAGE SURVEYS AND RECORDS—D. L. Hayner—WUA.

LOOKING FOR LEAKS AND FINDING THEM—R. W. Miller—AGA.

NEW LEAK-CALL TECHNIQUES—Dale Jobson—WUA.

USE OF LEAK DETECTORS IN SERVICE AND DISTRIBUTION WORK—E. G. Campbell—WUA.

LP gas plants

TRAINING OF PERSONNEL FOR OPERATION OF LP GAS PLANTS—S. C. Symnoski—AGA.

SOUND ENGINEERING SPELLS SAFETY IN LP GAS PLANTS—W. H. Kramer—AGA.

Meters

CURRENT APPLICATION OF METERING ECONOMICS—G. K. Bachmann—AGA.

DOMESTIC METERS, PERIODIC CHANGE-OUT PROCEDURE, RECORDS, SIZING AND METHODS OF INSTALLATION—Charles Rambau—M-WGA.

DRY CLEANING METERS AND REOILING DIAPHRAGMS—F. A. Sharkey—AGA.

INDUSTRY'S STAKE IN THE AGA-ASME LARGE DIAMETER METER TUBE RESEARCH AND TESTING PROGRAM—Ernest E. Stovall—AGA.

LARGE CAPACITY METERS, SIZING, REPAIRING AND FLOW TESTING—L. A. McGowan—M-WGA.

METER AND REGULATOR SHOP EQUIPMENT—Charles D. Peterson—M-WGA.

PRIMER ON ORIFICE MEASUREMENT—A. B. Lauderbaugh—AGA.

STANDARD DETERMINATION OF METER CAPACITIES FOR DIAPHRAGM-TYPE POSITIVE DISPLACEMENT METERS—Charles T. Collett—Committee report, AGA.

Synthetic Gas Meter and Regulator Diaphragms—J. K. Vetter—M-WGA.
Training Meter Shop Employees—James W. Chrisman—AGA.
Transporting Gas Meters, Problems and Solutions—Paul Laushman—M-WGA.

Miscellaneous

Black Iron or Equivalent—William M. Myler, Jr.—AGA.
Dynamometer for the Rapid Calibration of Air Motors—M. R. Engler—PCGA.

Odorization

Controlling Nuisance Odors at Odorization Stations—Paul L. Covell—AGA.
Investigation of New Odorants for Natural Gas—Interim Report #1, AGA.
Odor Evaluation and Records—Amos Abbott—WUA.
Odorization—Deane True, Monroe Boettcher, Thomas J. Lambeck, Marshall Hyde, W. J. Fitzgerald and Ted Welton—WUA.

Peak shaving

Burner Flexibility on Base and Peak Load Gases—Walter B. Kirk—AGA.
Economics of Peak Shaving—J. W. Carroll—AGA.
Economics of Peak Shaving—Hall M. Henry—AGA.
Keeping Plants in Standby Operation—Mervyn K. Wrench—WUA.
Influence of Substitute Gas Composition on Interchangeability with Natural Gas—D. L. Nicol, H. R. Linden and R. A. Brown—AGA.
Interchangeability of Oil Gas with Natural Gas—Interim Report, AGA.
Problems Encountered in the Operation of a Standby High Btu Oil Gas Plant—Glenn M. Hammond—AGA.
Production of Oil Gases as Substitutes for Natural Gas—H. R. Linden, J. J. Guyer, C. A. M. Hall and C. H. Riesz—AGA.

Personnel training

Packaged Service Training—John McLarty and W. C. Peters—AGA.
Training Meter Shop Employees—James W. Chrisman—AGA.
Training of Personnel for Operation of LP Gas Plants—S. C. Symnoski—AGA.
Training Truck Approach to Field Training Problems—G. M. Babbe—PCGA.

Pipe protection

Cathodic Protection—D. L. Hayner—WUA.
Cold Flow of Pipe Coating Bitumens—C. E. Lee—PCGA.
Corrosion and Cathodic Protection—D. L. Hayner—WUA.
Corrosion Protection of Natural Gas Main in Greater New York—F. E. Kulman—AGA.
Electrolysis Protection of Underground Structures—N. P. Pfeifer—PGA.
Galvanic Electrolysis Control—V. T. Penny—M-WGA.
Investigation of Magnesium Anode Installations in the Gas Distribution System—H. M. McCamish—PCGA.
Localized Cathodic Protection Using Magnesium Anodes—P. F. Offerman—PCGA.
Recycling Timer for Interrupting Cathodic Protection Test Currents—D. J. Waldie—PCGA.
Satisfactory Truck for Corrosion Control Work—F. O. Walters—PCGA.
Soil Resistivity Instruments and Measurements—O. W. Wade—AGA.
Use of Polyvinyl Chloride Tapes for Pipe Protection—George M. Carter, Jr. and T. J. Skotnicki—M-WGA.

Regulators

Automatic Loading and Boosting Type Regulators—G. W. Chipley and Paul Payton—WUA.
Fundamental Principles of Gas Regulation—H. M. Meuffels—M-WGA.
Gas Regulation and Noise Control—F. M. Partridge—PCGA.
Medium and High Pressure Regulator Settings—W. P. Dick—AGA.
Meter and Regulator Shop Equipment—Charles D. Peterson—M-WGA.
Pressure Control and Relief Devices for District Regulators—H. A. Hoehne—M-WGA.
Preventing Pilot Valve Stoppages with Fixed Orifices—C. H. Consterdine—PCGA.
Synthetic Gas Meter and Regulator Diaphragms—J. K. Vetter—M-WGA.

Research

Application of Automatic Ignition Systems to Commercial Gas Cooking Equipment—Research Bulletin 65, AGA.
Comparative Performances of a Warm-Air Ceiling Panel System and a Convection System—University of Illinois Engineering Experiment Station—AGA.
Comparative Study of Various Methods of Cooking—Research Report 1176—AGA.
Corrosion of Metals and Materials by the Products of Combustion of Gaseous Fuels—Report 3, Project DGR-4-CH, AGA.
Expansion Behavior of Coal during Carbonization—Research Bulletin #11, AGA.
Flame-Stability Limits of Methane, Hydrogen and Carbon Monoxide Mixtures—Joseph Grumer and Margaret E. Harris—AGA.
Gas Production Research in Review—F. J. Pfluke—AGA.
Heat Application in Gas Oven Cookery—Research Report 1182, AGA.
Industry's Stake in the AGA-ASME Large Diameter Meter Tube Research and Testing Program—Ernest E. Stovall—AGA.
Interchangeability of Oil Gas with Natural Gas—Interim Report, AGA.
Investigation of New Odorants for Natural Gas—Interim Report #1, AGA.
Investigation of the Pressure Characteristics and Air Distribution in Box-Type Plenums for Air Conditioning Duct Systems—University of Illinois Engineering Experiment Station—AGA.
Manual for the Design of Box-Plenum Type Air Conditioning Duct Systems—Project DGR-2-AC, AGA.
Mechanism of the Water-Gas Reaction, Rate of the Carbon-Steam Reaction—Gas Production Research Bulletin #4, AGA.
Performance of a Gas-Fired Forced-Air Heating System in a Research Residence—University of Illinois Engineering Experiment Station—AGA.
Physical-Chemical Properties of Methane-Nitrogen Mixtures—Research Project, AGA.
Selection of Oils for Carburetted Water Gas—Research Bulletin #9, AGA.
Selection of Oils for High-Btu Oil Gas—Research Bulletin, AGA.
Study of Combustion Characteristics of Fuel Gases—Interim Report #1, AGA.
Study of Performance Characteristics of Gas Boilers Equipped for Hot Water and Space Heating Services—Research Report 1185, AGA.
Study of Table-Top Water Heaters—Research Report 1186-A, AGA.
Study of Various Methods of Heat Application to Commercial Equipment: Deep-Fat Fryers—Research Bulletin 66, AGA.
Sulphur Poisoning of Nickel Catalysts—Research Bulletin #10, AGA.

River crossings

Analysis and Design of Pipeline Spans—P. E. Reynolds—PCGA.
Design of Gas Piping on Bridges—E. G. Watkins—AGA.
Flood Characteristics of Alluvial Streams Important to Pipeline Crossings—R. T. Knapp—PCGA.

Safety

Performance of Work Under Conditions Where Personnel Is Exposed to Leaking Gas—W. H. Krammes—PCGA.
Periodic Safety Inspections as Made Through the East Ohio Meter Reader Inspection Plan—Kenneth Wood—AGA.
Public Safety and the Gas Utility—Alfred L. Dowden—M-WGA.
Relief Devices for Distribution Mains—Michigan Consolidated Gas Co.—WUA.
Report on Public Safety Activities of the American Gas Association—C. E. Bennett—AGA.
Safe Operation of Compressor Stations—Edgar A. Koenig—AGA.
Safe Practice in Coal Gas Production—Walter T. Deveney—AGA.
Safe Practice in Water Gas Production—Willard E. Lebo—AGA.
Safety and Resuscitation—C. A. Coutts—M-WGA.
Safety in Transmission Line Maintenance—W. A. Johnson, Jr.—AGA.
Sound Engineering Spells Safety in LP Gas Plants—W. H. Kramer—AGA.
Wisconsin Gas Safety Code Developments—Vance Uhlmeyer, G. G. Ellerbrock—WUA.

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NEW TECHNICAL LITERATURE

Automotive equipment

CLEVELAND MODEL 80 TAMPER, BACKFILLER, SIDE CRANE. *Bulletin S120.* The Cleveland Trencher Co., 20100 St. Clair Ave., Cleveland 17.

DITCH BRIDGE. *Bulletin DBI-452.* Magnesium Products of Milwaukee, 748 W. Virginia St., Milwaukee 4.

HYDROCRANE BULLETIN. *Bulletin H-U-1.* Bucyrus-Erie Co., South Milwaukee, Wis.

SERVICE AND MAINTENANCE TRUCK BODIES. *Bulletin 113, 114.* McCabe-Powers Auto Body Co., St. Louis 15, Mo.

Coatings and pipe protection

ALUMINUM MASTIC. Royston Laboratories, Inc., Blawnox, Pa.

ASBESTOS PIPE LINE FELT. Middle West Coating & Supply. P. O. Box 153, Tulsa.

COLD-APPLIED PIPE MASTICS. Royston Laboratories, Inc., Blawnox, Pa.

CORROSIVE PROTECTIVE PLASTIC PAINT. The Corrosite Corp., Chrysler Building, New York 17.

GLAS-WRAP PIPE PROTECTION. Royston Laboratories, Inc., Blawnox, Pa.

PHENOLIC RESIN COATING, BAKED ON. *Bulletin S-5252.* Ric-Wil Plastic Coating and Manufacturing Corp., 1290 Euclid Ave., Cleveland 15.

PHENOLIC RESIN COATING, COLD SETTING. *Bulletin S-5251.* Ric-Wil Plastic Coating and Manufacturing Corp., 1290 Euclid Ave., Cleveland 15.

PROTECTIVE COATINGS. David E. Long Corp., 220 E. 42nd St., New York 17.

ROYSTON GLAS-WRAP. Royston Laboratories, Inc., Blawnox, Pa.

Combustion safety equipment

AUTOMATIC FIRE CHECKS AND SAFETY BLOWOUTS. *Bulletin SC-1006.* Selas Corporation of America, Philadelphia 34.

Communications

COMMUNICATIONS EQUIPMENT. *Wide range of catalog sheets.* Communications and Electronics division, Motorola, Inc., Chicago 51.

P-A-X BUSINESS TELEPHONE SYSTEM. *Bulletin 1735.* Automatic Electric Sales Corp., 1033 W. Van Buren St., Chicago 7.

Furnaces, industrial

CASE HARDENING. *Bulletin SC-159.* Surface Combustion Corp., Toledo 1.

DIRECT-FIRED FURNACES. *Bulletin SC-156.* Surface Combustion Corp., Toledo 1, Ohio.

GAS FIRED POT FURNACES. *Bulletin 22.* Lindberg Engineering Co., Chicago 12.

GAS FIRED TEMPERING FURNACE. *Bulletin 53.* Lindberg Engineering Co., Chicago 12.

HEAT PROCESSING BATCH LIQUIDS WITH DURADIANT CLUSTERS. *Bulletin SC-1015.* Selas Corporation of America, Philadelphia 34.

MAGNESIUM MELTING, HOLDING AND ALLOYING FURNACES. *Bulletin 500.* Lindberg Engineering Co., Chicago 12.

STATIONARY CRUCIBLE MELTING FURNACES. *Bulletin 301.* Lindberg Engineering Co., Chicago 12.

STEAM-PAK GENERATORS. York-Shipley, Inc., York 4, Pa.

WHY HEAT PROCESSING? *Bulletin S-7.2.* Selas Corporation of America, Philadelphia 34.

Gas-air conditioners

FLUID PROCESSING. *Bulletin S-7.3.* Selas Corporation of America, Philadelphia 34.

LIQUI-JECTORS. *Bulletins SC-1007-1008.* Selas Corporation of America, Philadelphia 34.

Gas analyzers

INDICATING AND RECORDING FLUE GAS ANALYZER. *Data Sheet 10-15.* Station 40, Minneapolis-Honeywell Regulator Co., Philadelphia 44.

MSA OXYGEN INDICATOR. *Bulletin Dw-4.* Mine Safety Appliances Co., Pittsburgh 8.

PRECISE OXYGEN DETERMINATION FACILITATED THROUGH INSTRUMENTATION. *Data Sheet No. 10.15.* Station 40, Minneapolis-Honeywell Regulator Co., Philadelphia 44.

Gas burners

GAS BURNER NOZZLES. *Catalog 804C.* Hauck Manufacturing Co., 124 10th St., Brooklyn 15.

GAS BURNERS, JET TYPE, HIGH INPUT WITH FLAME CONTROL. *Bulletin 52 K-1.* Killam Gas Burner Company, Denver 9.

GAS-OIL BURNERS. *Bulletin 12-S.* The Mettler Co., Inc., Los Angeles 63.

INDUSTRIAL COMBUSTION EQUIPMENT. *Catalog 52.* Hauck Manufacturing Co., Brooklyn 15.

P-R GAS BURNERS. *Bulletin SC-1000.* Selas Corporation of America, Philadelphia 34.

REFRAK SCREEN BURNERS. *Bulletin SC-1009.* Selas Corporation of America, Philadelphia 34.

TUNNEL BURNER. *Bulletin 807.* Hauck Manufacturing Co., 124 Tenth St., Brooklyn 4, N. Y.

Gas dehydration equipment

SELAS DEHYDRATORS. *Bulletin SC-1013* Selas Corporation of America, Philadelphia 34.

Heat processing equipment, industrial

CASE HARDENING. *Bulletin SC-159.* Surface Combustion Corp., Toledo 1.

DIRECT-FIRED FURNACES. *Bulletin SC-156.* Surface Combustion Corp., Toledo 1.

GAS FIRED POT FURNACES. *Bulletin 22.* Lindberg Engineering Co., Chicago 12.

GAS FIRED TEMPERING FURNACE. *Bulletin 53.* Lindberg Engineering Co., Chicago 12.

HEAT PROCESSING BATCH LIQUIDS WITH DURADIANT CLUSTERS. *Bulletin SC-1015.* Selas Corporation of America, Philadelphia 34.

INDIRECT COIL HEATERS. *Bulletin C-101.* Black, Sivalls & Bryson, Inc., Oklahoma City.

KEMP COMBUSTION EQUIPMENT. *Catalog B-11.* C. M. Kemp Manufacturing Co., 405 E. Oliver St., Baltimore 2.

MAGNESIUM MELTING, HOLDING AND ALLOYING FURNACES. *Bulletin 500.* Lindberg Engineering Co., Chicago 12.

PREPARED GAS ATMOSPHERES. *Bulletin SC-155.* Surface Combustion Corporation, Toledo.

STATIONARY CRUCIBLE MELTING FURNACES. *Bulletin 301.* Lindberg Engineering Co., Chicago 12.

WHY HEAT PROCESSING? *Bulletin S-7.2.* Selas Corporation of America, Philadelphia 34.

Instruments and controls

ALNOR PYROTAC AUTOMATIC PROTECTION. *Bulletin 4703.* Illinois Testing Laboratories, Inc., 432 N. LaSalle St., Chicago 10.

ARMORED FLOWRATOR METERS. *Bulletin 40.* Fischer & Porter Co., Hatboro, Pa.

AUTOMATIC CONTROL SYSTEMS. *Bulletin 1086.* Rockwell Manufacturing Co., Pittsburgh 8.

BAILEY AIR-OPERATED COMBUSTION CONTROL. *Bulletin 1023.* Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10.

CAM PROGRAMMER THERMOMETERS. *Catalog 6020.* Station 40. Minneapolis-Honeywell Regulator Co., Philadelphia 44.

COMPOSITE CATALOG. *Catalog 5000.* Station 40, Minneapolis-Honeywell Regulator Co., Philadelphia 44.

ELECTRIC CONTROL THERMOMETERS. *Catalog 6482.* Minneapolis-Honeywell Regulator Co., Philadelphia 44.

ELECTRONIC STRIP-CHART POTENTIOMETERS AND BRIDGE INSTRUMENTS. *Bulletin P1245.* The Bristol Co., Waterbury 20, Conn.

ELECTRONIK SCANNING SYSTEM AUTOMATICALLY MONITORS UP TO 270 TEMPERATURE POINTS. *Data Sheet 10.0-9.* Station 40, Minneapolis-Honeywell Regulator Co., Philadelphia 44.

FOXBORO CONTROLS. *Bulletin 461.* The Foxboro Co., Foxboro, Mass.

GAS CONTROLS. *Bulletin V5.* Minneapolis-Honeywell Regulator Co., Merchandising division, Minneapolis 8.

GAS PRESSURE IN CONSUMER AREA HELD CONSTANT. *Data Sheet 7.2-5.* Station 40, Minneapolis-Honeywell Regulator Co., Philadelphia 44.

HAND PYROMETER. *Sheet GEC-836.* General Electric Co., Schenectady 5, N. Y.

INSTRUMENT PRESSURE CONTROL SYSTEM. *Bulletin 1080.* Pittsburgh Equitable Meter division, Rockwell Manufacturing Co., Pittsburgh 8.

INSTRUMENTS FOR SCIENCE AND INDUSTRY. F. W. Dwyer Manufacturing Co., 317 S. Western Ave., Chicago 12.

PIPELINE INSTRUMENTATION DATA SHEETS. *Data Sheets 783-15, 16, and 17.* The Foxboro Co., Foxboro, Mass.

PRESSURE GAUGES WITH CONTROLS. *Specification Sheets 708, 709, 710.* Station 40, Minneapolis-Honeywell Regulator Co., Philadelphia 44.

PRESSURE PILOT. *Bulletin 16-1.* Station 40, Minneapolis-Honeywell Regulator Co., Philadelphia 44.

PYR-O-VANE CONTROLLER. *Sheet 114.* Minneapolis-Honeywell Regulator Co., Station 40, Philadelphia 44.

RADIAMATIC PYROMETERS. *Catalog 9300.* Minneapolis-Honeywell Regulator Co., Station 40, Philadelphia 44.

THERMOCOUPLES, RADIATION DETECTORS, RESISTANCE BULBS. *Bulletin TC-9.* Barber-Colman Co., Rockford, Illinois.

THERMOCOUPLES. *Catalog EN-S2.* Leeds & Northrup Co., Philadelphia 44.

THERMOHNS. *Catalog EN-S4.* Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44.

THERMOSWITCH THERMAL CONTROLS. *Catalog 400.* Fenwal, Inc., Ashland, Mass.

VARIABLE-AREA FLOW METER HANDBOOK. *Publication 10596.* Fischer & Porter Co., Hatboro, Pa.

LPG equipment

LPG-LPGA TRANSFER UNIT. *Bulletin H-609-B1.* Worthington Corp., Harrison, N. J.

Meters, valves and regulators

ADJUSTABLE FLOW VALVES FOR GAS AND AIR. *Catalog 713.* Hauck Manufacturing Co., 136 10th St., Brooklyn 15.

AIR-OPERATED BUTTERFLY VALVES. *Catalog 1700.* Minneapolis-Honeywell Regulator Co., Station 40, Philadelphia 44.

DESIGN ADVANTAGES OF SPENCE REGULATORS. *Bulletin 700.* Spence Engineering Co., Inc., Walden, N. Y.

DOUBLE SEATED DIAPHRAGM REGULATING VALVES. *Bulletin 513.* Leslie Co., Lyndhurst, N. J.

EMCO "1001" REGULATORS. *Bulletin 1059-2.* Pittsburgh Equitable Meter division, Rockwell Manufacturing Co., Pittsburgh 8.

EMCO PILOT LOADING SYSTEM. *Bulletin 1055-2.* Pittsburgh Equitable Meter division, Rockwell Manufacturing Co., Pittsburgh 8.

FIELD REGULATORS. *Bulletin 1024-3.* Pittsburgh Equitable Meter division, Rockwell Manufacturing Co., Pittsburgh 8.

FLOW METERS. *Bulletin F1605.* The Bristol Co., Waterbury, Conn.

LARGE CAPACITY GAS METERS. *Bulletin 1085.* Rockwell Manufacturing Co., Pittsburgh 8.

LOW PRESSURE BALANCED VALVE REGULATORS. *Bulletin 1082.* Rockwell Manufacturing Co., 400 N. Lexington Ave., Pittsburgh 8.

MAINTENANCE AND REPAIR MANUAL, NORDSTROM VALVES. *Bulletin V-206.* Nordstrom Valve Division, Rockwell Manufacturing Co., Pittsburgh 8.

PRESSURE REGULATOR. *Bulletin 52.* Detroit Regulator Co., 1742 Rivard, Detroit 7.

ROCKWELL "120" REGULATORS. *Bulletin 1044-4.* Rockwell Manufacturing Co., Pittsburgh 8.

SERVICE REGULATORS. *Bulletin 1026-1.* Rockwell Manufacturing Co., Pittsburgh 8.

Odorizers

ODORIZER UNIT. *Bulletin 902 and 903.* Peerless Manufacturing Co., P. O. Box 7193, Dallas 9.

Plastic pipe and fittings

JOHNSONSITE PLASTIC PIPE. *Bulletin 352.* Johnson Plastic Corporation, Chagrin Falls, O.

PLASTIC GAS PIPE. Golden Bear Manufacturing Co., Los Angeles 22.

PLASTIC PIPE. Anesite Co., Lincolnwood, Ill.

PLASTIC PIPE AND FITTINGS. Golden Bear Manufacturing Co., Los Angeles 22.

PLASTIC REPLACEMENT OF OLD STEEL GAS SERVICE. Golden Bear Manufacturing Co., Los Angeles 22.

TELSCO . . . FITTINGS FOR JOINING PLASTIC OR STEEL PIPE. Texas Lawn Sprinkler Co., Inc., 5422 Redfield St., Dallas.

Processing techniques

CASE HARDENING. *Bulletin SC-159.* Surface Combustion Corp., Toledo 1.

PREPARED GAS ATMOSPHERES. *Bulletin SC-155.* Surface Combustion Corporation, Toledo.

PROCESSING SULFUR BEARING GASES. The Fluor Corp., Ltd., Los Angeles 22.

Refractories

PLIBRICO REFRACTORY PRODUCTS. *Bulletin 11.* Plibrico Jointless Firebrick Co., Firebrick, O.

Tools

BARCO RAMMER. *Bulletin 621.8.* Barco Manufacturing Co., Dept. R62, 1801 Winnemac Ave., Chicago 40.

BEAVER PIPE TOOLS. Beaver Pipe Tools, Inc., Warren, O.

CONCRETE SAWS. *Bulletin 163 and 19.* The Clipper Manufacturing Co., Kansas City 8, Mo.

IMPERIAL 2-IN-1 TUBE BENDER. *Bulletin 3001-A.* The Imperial Brass Manufacturing Co., 1200 W. Harrison St., Chicago 7.

BIBLIOGRAPHY OF TECHNICAL PRESENTATIONS BEFORE GAS ASSOCIATIONS

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Servicing and service practices

ANALYSIS AND DESIGN OF PIPELINE SPANS —P. E. Reynolds—PCGA.

CUSTOMER EMERGENCY SERVICE—Robert Hannon—WUA.

HOUSE HEATER SERVICING—C. S. Hazel—AGA.

METHODS OF COST CONTROL IN CUSTOMER SERVICE—N. H. Gellert, Jr.—PCGA.

PACKAGED SERVICE TRAINING—John MacLarty and W. C. Peters—AGA.

SERVICE PRACTICES OF PCGA MEMBER COMPANIES—W. L. Kimsey, C. C. Underwood and Jack Kamrar—PCGA.

SERVICING THE ELECTRICAL COMPONENTS OF GAS APPLIANCES—P. L. Speers—PCGA.

USE OF LEAK DETECTORS IN SERVICE AND DISTRIBUTION WORK—E. G. Campbell—WUA.

Standby plants

INTERCHANGEABILITY OF OIL GAS WITH NATURAL GAS—Interim Report, AGA.

KEEPING PLANTS IN STANDBY OPERATION—Mervyn K. Wrench—WUA.

STANDBY GASES AND EQUIPMENT—A. C. Rathkey—M-WGA.

Transmission

COMPUTATION OF FLOW CONDITIONS IN GAS PIPELINES BY THE McILROY FLOW NETWORK ANALYZER—C. L. Barker—PCGA.

DEVELOPMENTS IN MECHANICAL EQUIPMENT FOR UNDERGROUND WORK—C. R. Newlin—AGA.

GAS TURBINE'S PLACE IN GAS PIPELINE PUMPING—J. O. Stephens—AGA.

HYDROSTATIC TEST OF A 22" TRANSMISSION LINE—W. L. Masheter—PCGA.

MAIN CONDITIONING FOR LEAK CONTROL, CLEANING MAINS AND DUST FILTERS—Thomas J. Lambeck and R. K. Levey —WUA.

PIGS IN HYDROSTATIC TESTS ON LARGE DIAMETER PIPELINES—M. J. Binckley —PCGA.

PIPE LINE WELDING—Leonard J. Cunningham—M-WGA.

PRESSURE CONTROL EQUIPMENT FOR USE ON 16-INCH PIPELINES—Paul Wright —PCGA.

STEAM CENTRIFUGAL COMPRESSORS, REPORT TO THE INDUSTRY—F. B. Haverfield—AGA.

TRANSMISSION OPERATING PROBLEMS—E. F. Hindman and T. S. Whitis—SGA.

Underground gas storage

OPERATION OF LA GOLETA GAS STORAGE FIELD—Raymond W. Todd—AGA.

POTENTIALITIES OF THE HERSCHER DOME AS A GAS STORAGE RESERVOIR—M. V. Burlingame—AGA.

STATISTICS FOR OPERATIONS OF STORAGE FIELDS—John V. Goodman—AGA.

STORAGE OF GAS IN A PARTIALLY DEPLETED OIL ZONE, PLAYA DEL REY FIELD, CAL.—John Riegle, Jr.—AGA.

Valves

NEW TWIST TO VALVES—E. C. Paige and E. J. Gay—AGA.

PREVENTING PILOT VALVE STOPPAGES WITH FIXED ORIFICES—C. H. Consterdine—PCGA.

Welding

REPORT ON THE NEW SPECIFICATIONS FOR FIELD WELDING AND RADIOGRAPHIC TESTING OF PIPELINES—Robert G. Strong—AGA.

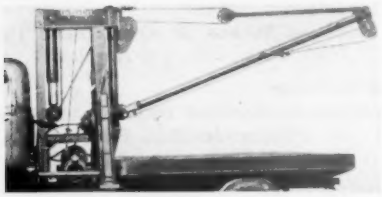
PIPE LINE WELDING—Leonard J. Cunningham—M-WGA.

NEW EQUIPMENT

AUTOMOTIVE

Hydraulically-powered crane boom

A recently-developed crane with hydraulically-powered boom that can be mounted on the frame of any truck, 1½ tons or larger, has been placed in production. According to the manufacturer, the new crane requires 40" behind the cab of a truck, has a loadline capacity of 6,400 pounds and a swinging boom which telescopes from 12 to 22 feet. Improvements in the new model are (1) an increase in the unit's safety margin and (2) it is shipped almost completely pre-assembled, cutting the time and cost of

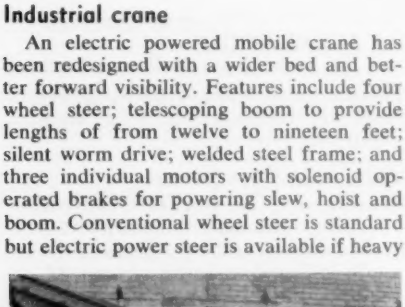


installation. The crane was especially designed for unloading, loading, stringing and laying pipe. Mounted on a truck fitted with a bolster and pipe trailer, a long wheelbase truck or a tractor-trailer unit, the crane can load to the truck on which it is mounted, then travel to the job. It also sets heavy valves and serves as a winch. In addition, the unit has uses in a pipe yard, handling valves, fittings, and meters.

Hydra-Lift. Pitman Mfg. Co., Kansas City, Mo.

Industrial crane

An electric powered mobile crane has been redesigned with a wider bed and better forward visibility. Features include four wheel steer; telescoping boom to provide lengths of from twelve to nineteen feet; silent worm drive; welded steel frame; and three individual motors with solenoid operated brakes for powering slew, hoist and boom. Conventional wheel steer is standard but electric power steer is available if heavy



loads are to be handled. Crane capacity is 10,000 pounds at 5½ feet radius. With boom fully extended, a hook height of eighteen feet can be obtained. Overall length and width are 130⅝" and 66¾" respectively. 22" x 10" solid tires or 23¾" x 8" cushion tires can be supplied. The truck turns in 95 inch intersecting aisles. Maximum slew is 296°.

Model CZ. Elwell-Parker Electric Co., 4205 St. Clair Ave., Cleveland.

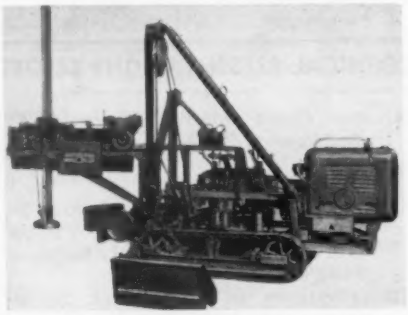
Public utility truck bodies

Two new truck bodies have been designed for public utility use. The compartments are equipped with shelves, trays, material hooks and parts bins. Also included is an overhead rack with adjustable brackets. The doors are of weathertight construction, with flush-mounted, slam-action handles and cylinder locks. Optional equipment includes telescopic roof, hinged ladder rack, side-mounted ladder rack, rear bumper-step and other accessories. Lengths of bodies in series 44, without superstructures, are 75", 90" and 104"; in series 44-L the lengths are 90" and 104".

Series 44 and 44-L Utility Bodies. McCabe-Powers Auto Body Company, St. Louis 15.

Tamper-backfiller-crane

This is a one-man machine that tamps, backfills, lays pipe, unloads and handles pipe, sheathing, etc. and does light crane work. The machine is mounted on a crawler having 24 separate travel speeds, ranging from one foot per minute up to 2⅛ miles per hour, coupled with high stability and maneuverability. Three-way simultaneous action, tamps and backfills as it travels, gives it speed in these operations. The



tamper delivers a 380 ft.-lb. blow, 45 times each minute. The backfiller is a conventional drag-line type with a telescopic boom. Elimination of all excess weight permits use over sidewalks and lawns with safety. It backfills from either side of trench. The power-operated boom is said to lay pipe speedily. Light crane duties involved in trench operations are within the scope of the machine. Without extra counterweights, it will lift a weight of 6,000 pounds, located three feet from the edge of the crawler track.

Model 80. The Cleveland Trencher Co., 20100 St. Clair Ave., Cleveland.

Hydraulic dump truck body hoist

A complete new line of hydraulic dump truck body hoists featuring design improvements has just been announced. Fourteen

models of this new hoist are available in a selection of capacities from 6 to 25 tons. The new body hoists are said to feature the lowest standard mounting height; also advanced lifting point, new low operating oil pressures, a new flexible subframe, friction-free roller bearing drive mechanism, including pump and power takeoff. A unique stress-eliminating design feature of the new hoists is claimed to almost entirely absorb dumping shocks and permits use of a new hoist principle.

St. Paul Hoist. Customer Service Dept., St. Paul Hydraulic Hoist, Wayne, Mich.

COATINGS, PAINT, WRAPPINGS

Protective coating

Three new types of neoprene liquid coating for maintenance purposes have been introduced. They can be brushed, sprayed, dipped, trowelled or rolled. These coatings are said to provide a uniform sheet of neoprene, with lasting protection against corrosion, chemicals and water, and they will not chip, crack or peel. One type is an all-purpose air-drying coating for applications against high temperature, steam, acid fumes and splashes, solvents and general wear. It is oil- and grease-resistant, resilient and non-porous. It may be used on metal, concrete or wood and is available in black, gray or red. Another coating is designed primarily for equipment protection such as heavy immersion service on valves, pumps, pipes, impellers and tanks. It may be applied to metal, wood or concrete. It is said to be chemically stable and resistant to most acids.

Mercer-Proco Liquid Neoprene Coating —All-purpose, N-700; Skidproof, N-600; Equipment-protection, N-200. Mercer Rubber Corp., 64 Reade St., New York 7, N. Y.

Pipe tape

A new polyvinyl chloride pipe tape is now available in 1" widths and the manufacturer states that it is particularly adaptable for wrapping fittings. This tape has an insulation resistance of 100,000 megohms and a dielectric strength of 10,000 volts, 10 mil. This tape is said to offer protection against water, salt water, acids, alkalies, oil and soil chemicals.

Dressertape. Dresser Manufacturing Division, Dresser Industries, Inc., Bradford, Pa.

Aluminum mastic

This mastic is said to provide a heavily embodied corrosion-resistant film, about ten times the thickness of aluminum paint. It is recommended for coating porous surfaces and metals against moisture and corrosion. It is plasticized.

Royston Aluminum Mastic. Royston Laboratories, Blawnox, Pa.

Heat resistant paint

A new ready-mixed aluminum paint has been made available for application to metallic surfaces as a protective finish for furnaces, pipes, boilers and ovens, withstanding temperatures to 1600°F. The manufacturer claims that the heating action serves to create a bonding effect. The paint is anti-corrosive and weather-resistant. It may be brushed, sprayed or dipped and dries within thirty minutes.

Super-Hot. Sheffield Bronze Paint Corp., 17814 Waterloo Rd., Cleveland 19.

Aluminum coating

This is claimed to be a bright finish aluminum coating of non-reactive composition, which is suited for spraygun application. It is recommended for coating equipment such as meters, regulators and valves. The manufacturer claims as special features: Will not spatter background surfaces four feet or more from spraygun; material dries to a cottony, non-adhering powder in four feet of travel.

Roylac Aluminum. Royston Laboratories, Inc., Blawnox, Penna.

Pipe wrapping

This glass fiber pipe wrapping fabric is for reinforcing pipe coating mastic and for protection against soil and rock abrasion. Claims are that the glass filaments are smooth, cylindrical and non-hygroscopic, and that it bonds readily to mastics.

Royston Glaswrap. Royston Laboratories, Inc., Blawnox, Penna.

COMBUSTION EQUIPMENT

Gas burners

Designed especially for use with natural and other slow-burning gases, a new series of burners is said to facilitate converting burner manifolds for the use of those gases. With a range of capacities from 1,500 to 5,000 Btu per hour, these burners are adaptable in the replacement of manufactured gas burners in hand torches, ribbon burners and sealing burners. The characteristic flame from these burners is hatchet-shaped and provides intense local heat. The manufacturer illustrates their adaptability in glass work and metal work. The burners are made of brass and are fluted to give maximum uniformity of flame in natural gas service. Pilot holes burn the air-gas mixture at a low velocity to support and retain the flame from the main burner holes. Flame lengths range from 2″ to 2½″, in accordance with the burner capacities. Burners made of heat resisting metal can be supplied for use with oxygen and gas.

Fishtail Burners. Research Vacuum Supply Co., 3434 Montrose Ave., Chicago 18.

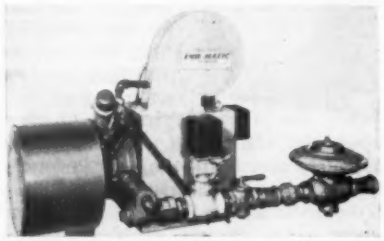
Atmospheric burners

Small and compact horizontal atmospheric gas burners are for heating installations requiring high input ratings and minimum space and burner size. Heavy welded housing and manifold are features, and jets are cast iron with integral flame retention nozzles. Jets and orifices can be changed without tools, and without disturbing the burner setting. Each burner has an input rating of approximately 1500 cfh natural gas at 4″ manifold pressure per square foot of face area. Ratings are proportional for other pressures, to two pounds. The burner is 3¼″ to 12⅝″ long; 3¼″ to 12¾″ high; 5½″ to 20½″ wide. Inputs vary from 87 to 1901 cfh.

P-8 Power Pak. Killam Gas Burner Co., 260 Broadway, Denver 9.

Combination gas-oil burner

An industrial and commercial burner designed for oil and gas provides for changeover from one fuel to the other,



instantly, with a switch. This burner is said to make it possible to alternate fuels according to availability, economy or suitability. Among the features, says the manufacturer, are dual atomization, rotary flame action, simplicity of installation, all internal wiring and piping supplied, space-saving design, adjustable burner support, electronic flame failure control. Mixed, natural or LP gas, or number 1, 2, or 3 fuel oil may be used. Either gas or oil can be burned without induced secondary air.

Fyr-Matic Gas-Oil Burner. Eclipse Fuel Engineering Co., 1108 Buchanan St., Rockford, Ill.

Radiant tube carbonitriding furnace

A vertical radiant tube unit has been added to this manufactured carbonitriding furnace line. It is claimed that the lightweight vertical radiant tubes can be removed and replaced conveniently, eliminating production down-time. The furnace is rated at 250 net pounds an hour for hardening a flash case, dry cyaniding. It is packaged, with built-in quench system and automatic cycle control. It is said to be adjustable to produce different atmospheres not only for carbonitriding, but also for carburizing, annealing and bright hardening.

Hyen Endothermic Atmosphere Generator. Lindberg Engineering Co., 2450 W. Hubbard St., Chicago 12.

FILTERS

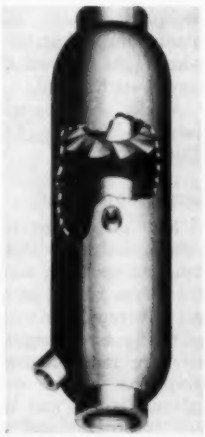
Replaceable air filter

This white replaceable type filter is for use in all forced air heating and cooling systems. Glass filaments are packed evenly across the air inlet side and then packed progressively tighter all the way to the air exit side, to trap dirt inside rather than on the face of the filter. The filaments are held in place with a thermoplastic bond. The filter is held in a fiberboard casing between metal grilles. It is odorless and non-greasy; there are no slivers of glass. The filter is available in standard sizes; special sizes on request.

Replaceable Filter. American Radiator & Standard Sanitary Corp., Pittsburgh 30.

Line type purifier

A line type purifier has been announced for piping from ½″ to 2″. It is said to be low priced permitting purifiers to be used in installations where they formerly were considered to be uneconomical. Applications: clean processing lines, protect small engines, turbines, and regulating equipment from solids, remove entrainment from vapor lines following evaporation or distillation. This purifier removes entrainment by means of centrifugal element which engages and imparts



a rapid rotational motion to entrainment laden vapor, throwing the solids and water to the walls of the unit. Units, warranted by the manufacturer to remove more than 99 per cent of the entrainment, are installed like valves or traps. Other features claimed: no moving parts, minimum pressure drop through the unit, lightweight construction and large entrainment capacity. For steam applications to 400 psig and 500° F. The body is forged steel with stainless centrifugal elements.

Type LC Hi-eF Purifier. Purifier division, The V. D. Anderson Co., 1935 W. 96th St., Cleveland 2.

INSTRUMENTS, CONTROLS

Combustible gas alarm

Completely explosion-proof in construction, this combustible gas alarm can be installed directly in the suspected atmosphere, indoors or out. Located in a bell-shaped cover housing, the sensing unit is weather-proof like all other parts of the unit. By convection and diffusion, the surrounding atmosphere is subjected to a continuous watch against the buildup of any kind of explosive vapors. Presence of such

vapor is signalled by a bright red indicator light as well as by remote alarm units of various types which can be connected to the terminals provided. While the standard alarm point is established at 0.2 of the lower explosive limit, other values can be provided where required. Either self-reset or lock-in arrangements can be provided to give a choice between an on-off indication of gas, or one which must be manually reset. The sensing unit can be located remotely from the rest of the alarm if de-

sired. Completely a-c operated, the alarm is designed for rough-service locations. It contains no meters or meter-type sensitive relays, but utilizes an electronic trigger-tube circuit to convert the sensing-unit signals into alarm indications. Stand-by power consumption from the 115 volt line is 15 watts. The alarm is applicable to pipeline pumping stations, liquefied-petroleum gas plants, and industrial and commercial areas where gas or volatile liquids are used, stored, or handled.

Model EE Combustible Gas Alarm. Johnson-Williams Ltd., 2669 Third St., Palo Alto, Cal.

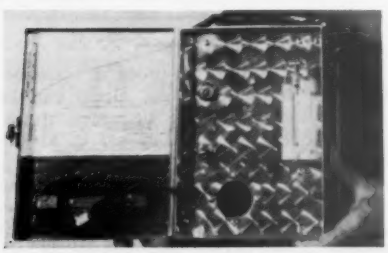
Gas calorimeter

This instrument is designed to record continuously the calorific value of gas of 80 Btu and up. It is simple in design. Gas is fed to the burner at a rate controlled by a gas flow regulator which compensates automatically for changes in atmospheric temperature and pressure conditions. The heat from the burner expands concentrically mounted tubes and the differential expansion is proportional to the calorific value of the gas. The tube movement is conveyed through a frictionless magnifying mechanism to a pen which records the calorific value on a calibrated chart. This instrument is said to be suitable for all types of gases and for wall or panel mounting. It does not need external connections except gas supply.

Sigma Calorimeter. Manufactured by Sigma Instrument Co., Letchworth, England; distributed by Cosa Corp., 405 Lexington Ave., New York 17, N. Y.

Odor-intensity meter

This recently developed odor-intensity meter, now in production for distribution to gas utility engineers, simulates a room test



for determining the threshold detection, odor strength and odor characteristics of natural and LP gas. The unit is housed in an aluminum case, and all parts which come in contact with gas are of aluminum or glass. The unit includes a 110-volt constant-speed electric motor driving a small turbine blower to deliver a constant volume of air into which odorized gas samples are measured through a rotameter. The air-gas sample is mixed in a tapered glass tube. Sniff tests at the top of the gas permit personal judgment of the characteristics and intensities of the odorized gas. A calibration chart provides the means for determining the necessary increase in odorant. The average range of the instrument is from less than 1/10 of 1 per cent to more than 1 per cent, the standard of measurement generally used for room testing of odorized gas. This meter may be used at any point on a distribution line. The instrument measures 6″ x 6″ x 8½″ and weighs 5½ pounds.

Oronite Odorometer. Oronite Chemical Co., 38 Sansome St., San Francisco.

Electronic timer

An electronic timer, capable of controlling timed operations between 60 milliseconds and 60 seconds, has been developed and announced. The discharge of a resistor-capacitor network through a sensitive gas tetrode relay tube provides the basis for each timing period, the duration of which may be set manually by a potentiometer.

Steps within the overall timing range are adequately covered by plug-in condensers. The time period is set manually by means of the indicator and dial. Timing commences upon closure of any external switch; control contacts either open or close at end of timing, depending upon actual circuit requirements. Control contacts are double pole double throw, rated at 10 amps, 125 volts a-c, non-inductive. Operation is from 115 or 220 volts a-c, 60 cycle. These timers may be mounted back-of-panel, against a wall, or in the rear of a cabinet. Wide-spaced barrier strips may be located either on the front or the back of the timers. Applications include: automatic process control and on machines.

Promatic Electronic Timer. General Control Co., Boston 34, Mass.

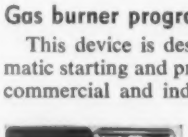
Gas appliance tester

A new gas appliance tester is designed for use by service and repairmen in their testing of gas appliances using thermostats, thermocouples and relays. The instrument is used directly on the job. This new tester will determine and measure the thermovoltage produced by the thermocouple, with or without the load of the magnetic assembly. Also, it measures the millivolts required for proper functioning of magnetic assemblies. The built-in meter indicates the repair steps that are necessary. The manufacturer states that the instrument can be used for continuity tests of relays, thermostats, wiring, coil assemblies, solenoids and heater coils.

M-Scope Gas Appliance Tester, Model G-20. Fisher Research Laboratory, Inc., 1961 University Ave., Palo Alto, Cal.

Gas burner programming control

This device is designed to provide automatic starting and programming control for commercial and industrial gas and combination gas-oil burner equipment. The control automatically starts a burner in operation and programs a sequence of pre-purge, ignition-on, fuel valve delay, post-ignition timing and post-purge. It is claimed to have instantaneous response to flame failure, with complete fuel cut-off in two to four seconds, providing protection from explosion hazards. A built-in time delay prevents false shutdown from transient effects such as smoky streaks in the flame or irregular draft conditions. Cam assembly construction permits programming variations. The control is designed to provide continuous operation on industrial installations and is labeled by Underwriters' Laboratories Inc., and Factory Mutual Laboratories.



Fireye Programming Control Type 26RJ8. Combustion Control Corp., 77 Broadway, Cambridge 42, Mass.

Gas odor intensity indicator

This instrument, designed to measure odor thresholds and levels in fuel gases has been introduced. The instrument is said to be equally effective on LP, natural or manufactured gas. The instrument is engineered to fill the need for a small, portable instrument to measure odor thresholds in LP gases. According to the manufacturer, the meter will accurately, safely and simply show the odor intensity of any type of fuel gas within the lower limits of combustibility, anywhere within a distribution system. It is said to take the guesswork out of odorizing processes and odor detection. The exact gas-air mixture at which odor is detectable is indicated on a gauge and is instantly readable without reference to graphs, scales or specific gravity charts. It will test and indicate the levels of odor intensity well within the requirements of the various state and national requirements. The one-unit device measures 3″ x 6″ x 7″ and weighs 54 ounces, and can be used either in-or-outdoors.

Odicator. United Petroleum Gas Co., 806 Andrus Bldg., Minneapolis 2.

PIPE CONNECTIONS

Pipeline welding joint

This product permits welding a pipeline together while pumping gas through it and eliminates danger of bellhole fires or explosions when rejoining a "hot" line by welding, it is claimed by the manufacturer. This device is available in sizes from 2″ up to 36″, and larger if required, is applied around the pipe ends, tightened and welded in place. In sizes from 2″ to 10″ it is machined in turret lathes from seamless steel tubing. In larger sizes, 12″ to 36″, it is made from mild carbon steel plate.

Weld + Ends. Pipe Line Development Co., 2536 Euclid Ave., Cleveland 15.

Threadless pipe connector

No thread cutting is required, the manufacturer states, to use a new factory-assembled pipe coupling in which pipes are connected with couplings by tightening lock nuts. Working pressures to 2,000 psi are claimed for this coupling which is made of pipe steel and cold rolled steel

using a compression rubber gasket. Applications to gas systems are recommended by the manufacturer. The coupling is available in from ½" to 1½" ips.

Quik-Joint. Quik-Joint Manufacturing Co., Harvey, Ill.

Insulated pipe union

A new insulated pipe union for residential water heaters to prevent galvanic corrosion of water tanks has been developed.

Required in both hot and cold water lines, the new pipe union acts as an electrical circuit break between the copper and steel. The union is made of galvanized malleable iron, nylon, and zinc plated steel. At present, it is manufactured in ¾" pipe size with a ¾" female pipe connection on each end. It is also available with ½" and ¾" sweat or solder connections on the pipe end. Other sizes will be produced.

Universal Type 2000 Pipe Union. Universal Controls Corp., Dallas, Tex.

Leak clamps

A fast repair, with small investment, and less chance of future breaks in the strain area are claimed for this new clamp for full breaks in lines. Construction is of 36-ounce copper or 20-gauge stainless steel sleeves, a new lug which eliminates bolt bending and a special rubber gasket. The manufacturer has announced a new high pressure leak repair clamp for repairing corroded pipe sections, leaks, and breaks which do not extend fully around the circumference of the pipe. It is made of 36-ounce cold rolled heavy copper band, 18-gauge galvanized iron band, or 20-gauge stainless steel band. Clamp widths are 3", 6", 7½", 10", 12½" and 15".

CirclSeal. HiPressure. R. H. Baker & Co., Inc., Huntington Park, Calif.

PLASTIC PIPE, FITTINGS

Fittings for plastic or steel pipe

A line of malleable iron threadless fittings for joining standard-size plastic or steel pipe, with ten different types and 111

different sizes is being offered. Fittings available are couplings, adapters, 90° elbows, adapter elbows, tees (straight and reducing), tees (with threaded branches), and reducers and increasers. The size range is from ½" through 2". Fittings are factory-assembled and ready to use on plain-end pipe, without threading. Pipe end is simply inserted into fitting, and fitting end nuts tightened with an ordinary wrench. Besides eliminating the time and labor of threading, the fittings produce a stronger connection because pipe wall is not weakened by threading, the manufacturer claims. Rubber gaskets inside the fittings protect pipe from the strains of contraction, expansion and vibration. Fittings hold joint permanently tight, are not affected by the properties of air, water, gas, gasoline, butane or propane, and will withstand temperatures to 275° F. The fittings are treated with a special rust preventative. Gaskets are neoprene. Fittings are said to be suited for use in original small-diameter plumbing installations or repairs, in industrial piping, chemical plants, gas piping, lawn sprinkler systems, machinery, appliances.

Telsco Fittings. Texas Lawn Sprinkler Co., Inc., Telsco Fittings division, 5422 Redfield St., Dallas.

Rigid plastic pipe, compression fittings

The development and production of an improved rigid plastic pipe and of a new design of compression-type coupling have been announced. The manufacturer states that these products have increased resistance to burst, high tensile and flexural strengths, greater chemical resistance and the ability to withstand sunlight. They maintain features of light weight, ease of handling, resistance to deteriorents. The pipe is supplied in 10- and 20-foot random lengths which can be connected by the new type of coupling or by slip-sleeve tees and ells. The feature described for the new fitting is that longitudinal force exerted on a rubber gasket incorporated into the fitting creates a secondary force at right angles to maintain a leakproof joint. Also, the new coupling is said to compensate for expansion and contraction of the rigid pipe. The pipe is available in standard sizes from ½" to 2" and threaded adapters are available for connection of the plastic pipe to metallic pipe.

Carlon Plastic Pipe and Compression Coupling. Carlon Products Corp., 10025 Meech Ave., Cleveland 5.

Plastic tubing

Thermosetting plastic and Fibreglas-reinforced tubing that is light in weight, with high strength, is available for use as standpipes and vent tubes, oil and gas lines, electrical conduits. The tubing is available in standard sizes from 4-10 inches o.d. with wall thicknesses ranging from .030 inches, and tensile strength to 35,000 psi and a flexural strength to 65,000 psi. Varying with diameter and reinforcement, burst pressures range to 3,000 psi. Straight sections of 20 ft. in length are coupled by cemented sleeves. The material is non-porous. Its operating temperatures range from minus 60° F to 230° F.

Reflin Tubing. Reflin Co., 8525 Higuera, Culver City, Cal.

Fittings for flexible plastic pipe

A new line of insert-type ell and tee couplings has been made available for use with flexible plastic pipe to facilitate making sharp turns or take-offs. The fittings are joined to the pipe by forcing the flexible tubing over the serrated ends of the fittings and then are sealed by tightening stainless steel clamps over the joint. The manufacturer claims that only a saw and screwdriver are necessary to make the connection in less than two minutes. An insert adapter is available for joining plastic pipe to metallic pipe, using threads at the metallic end and clamps on the plastic end. All fittings are of molded thermoplastic.

Carlon Fittings for Flexible Plastic Pipe. Carlon Products Corp., 10025 Meech Ave., Cleveland 5.

Flexible plastic pipe

Flexible plastic pipe intended for use as gas service lines in new or replacement work has been announced, with the manufacturer's guarantee against rot, rust and corrosion. Also, it is impervious to chemical actions, alkalies, sulphur and metallic salts. The manufacturer points to the ability of the pipe to absorb vibration stresses. Flexibility permits following irregular ditch contours and eliminates multiple use of fittings.

Carlon Flexible Plastic Pipe. Carlon Products Corp., 10225 Meech Avenue, Cleveland 5.

REGULATORS

Indoor gas service regulator

A new gas service regulator for indoor installation has been announced. It is said to be especially adaptable to the colder areas. Piping connects to the casing of the regulator for venting and relief valve discharge outdoors. Separate vents are provided for relief and breathing as protection against ice and insects.

An outside weatherproof and bugproof breather vent has been developed for use with this regulator. A new principle in regulator construction has been incorporated, the manufacturer states, with an auxiliary passageway in the stem guide piece carrying the pitot tube. With a cross section of approximately fifteen times that of the pitot tube, the passageway is kept closed in normal operation but is capable of opening instantly for emergency relief valve discharge. A doughnut-shaped check valve disc closes on a flat, raised seat at the left end of the stem guide piece, the disc hole making a sliding fit over the guide bushing. The disc is pliable enough to adjust itself to the check valve seat surface. The check valve action prevents "choking" in the vent connections. A variety of vent connections, welded to the spring case, is available.

Universal Series 51-R Regulator. Universal Controls Corp., Dallas, Tex.

Regulator equipment

Five new pieces of gas regulator equipment have been made available to the gas industry within the past year by one manufacturer. Outstanding improvements are claimed for the company's line of house service regulators. A new pitot tube assembly permits the body to be changed in the field to secure any one of four basic directions of gas flow with respect to the spring case. A new line of low pressure

precision controllers in 2″, 3″, and 4″ sizes was introduced. One type, for gas engines, industrial furnaces, and large appliances, is installed just ahead of burner manifolds where precision control is necessary. The manufacturer states that this precision control is met with widely varying inlet pressures or pressure drops. A new safety house service regulator has been placed in production. Its patented magnetic coupling operates to close off flow of gas completely if excessive pressure occurs in appliance piping, according to claims, and no gases are discharged to atmosphere, vent line requirements are simplified. This manufacturer also claims a new approach to protecting gas distribution systems against excessive pressure in a new relief valve, equipped with a full opening body that produces maximum capacity beyond conventional relief valves. It embodies a new pressure switching principle to discharge either small or large volumes of gas in response to a negligible increase over set pressure, as required. A new diaphragm relief valve was announced, incorporating a pitot booster feature to improve performance and capacity. It was designed to protect against excessive pressures in appliance or furnace lines downstream of large sized service regulators, even though the regulators failed in a wide open position. It is said to have application as a general service relief valve.

730 C Service Regulators. Type 66 Controller. Type 735 C Safety House Regulator. Type 29 Relief Valve. Type 289 Relief Valve. Fisher Governor Co., Marshalltown, Iowa.

Pneumatic pressure regulator

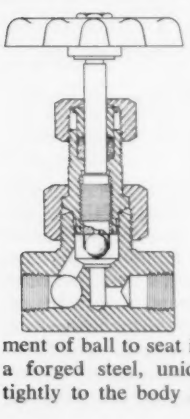
A new series of pneumatic pressure regulators intended for close regulation in industrial applications has been developed. The series is designed to reduce line pressures as high as 150 psi to required lower working pressures. They are available for ⅛″, ¼″ and ⅜″ pipe sizes, with or without filters and with pressure relief.

V-301 and V-302. General Controls Co., Los Angeles.

VALVES

Ball valve

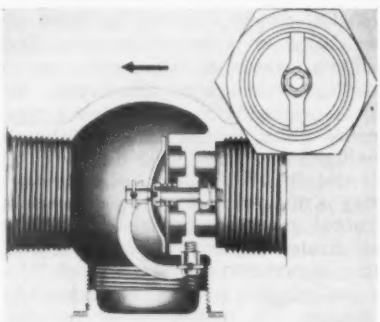
A new ¼-inch ball valve of unique construction, recommended by the manufacturer for working pressures up to 3,000 psi, has been announced. Tight, positive shutoff is provided by a stainless steel ball which closes into a machined, conical seat. The ball, retained at the end of the stem, is free-rolling so that every closing brings a new surface into contact with the valve seat. Alignment of ball to seat is accurately piloted by a forged steel, union-type bonnet, fitting tightly to the body and assuring a correct valve closure. The long-stroke stem and the packing gland are made of stainless steel for durability and resistance to corrosion. The packing is a preformed, graphited asbestos with a plastic binder and can be replaced without shutting off the line pressure or interrupting the process. Straight-through and angle types are available with two and four connections. Applications include meter manifolds, gauge lines, seal chambers, bleed-off and sampling connections. The valve is for liquid, gas and steam service.



Foxboro Ball Valve. The Foxboro Co., Foxboro, Mass.

Back pressure check valve

A patented horizontal, non-sticking, disc-type, back-pressure check valve for gas lines has been placed in new production. The valve permits unrestricted gas flow at negligible pressure drop with the light weight disc in full open position, at pressures as low as 1″ wc. If air back-pressure should exist on pre-mixed air and gas systems, the manufacturer claims the valve will close and prevent air from entering low pressure gas distributing lines. A spring-tensioned push-rod holds the aluminum disc slightly off the valve seat except in case of reverse flow. Gas flow to maintain pilots is said to be assured; the possibility of the disc sticking to the valve seat is minimized. The valve can be supplied with either aluminum or stainless steel discs, depending on back-pressure requirements to 125 psi. All parts are accessible for inspection and cleaning without removing the valve from the line.



The Callahan Valve. Henry Flow Control Co., Melrose Park, Ill.

Magnetic gas valve

A new 3½ pound capacity magnetic gas valve designed for pilot line service on high pressure burner installations has been added to this manufacturer's established line. The new valve is available for 115 or 230 volt service in ¼″ and ⅜″ sizes. A hammer-action plunger and a stainless steel seat cast into the valve body are pointed out as features.

V495 Magnetic Gas Valve. Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.

Automatic safety shut-off valve

An automatic safety shut-off valve is claimed to function when an over-pressure or over-temperature condition accurs. It is for installation on the upstream side of the meter. The valve is made of cadmium plated metals and brass. Seal and diaphragm are of long-life materials. The valves are manufactured in high pressure sizes of ¾″, 1″, and 2″; and in standard sizes of ¾″, 1″, 1½″, and 2″. Standard sizes have a rated pressure of 150 psi, test pressure of 225 psi, and an operating pressure range of 20″ wc to 2 lbs. High pressure sizes have a rated pressure of 400 psi, test pressure of 225 psi, and an operating pressure range of 50 psi, maximum.

Poly-Trol. The Handley Brown Heater Co., 2540 Brooklyn Rd., Jackson, Mich.

TOOLS

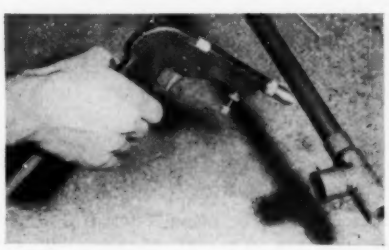
Pipe polishing wheel

A unique, air-inflated polishing wheel is said to polish pipe ends preparatory to joining with increased speed, convenience and safety, and will not undercut or grind flats. The wheel consists of a rubber drum 5″ in diameter with a 3½″ surface. The drum is mounted on a flange with either a ½″ or ⅝″ arbor. The operator slips an abrasive belt over the drum and then inflates the drum with from three to ten lbs. of air. Five to six lbs. is said to be about right for polishing pipe ends. The manufacturer claims that the wheel can be used with any kind of power tool for any type of polishing job. Belt changing is convenient. The resiliency of the wheel permits greater abrasive contact area, eliminates chatter and bounce, enables the wheel to polish contours more efficiently and safely. Users claim abrasive belt life lengthened.

Nu-Matic Grinder. Nu-Matic Grinders, Inc., 8224 Carnegie Ave., Cleveland 3, O.

Acetylene-air gas torch

A new pistol-shaped torch, with trigger lighting and shutoff, is recommended by the manufacturer for intermittent operations in soldering work. It is also said to be effective for precision work. It is intended for one-hand operation, weighs 12 ounces and provides heat to 2,800°F. Combustion tubes are available in three sizes.



Torch-O-Matic. Velocity Power Tool Co., Pittsburgh 8.

Concrete saws

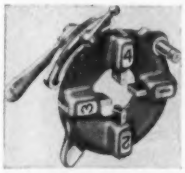
This manufacturer offers five models of portable concrete saws, two gasoline powered models and three electrically powered models. It is said that one of these can be used as a wet (dustless) or dry cutting

masonry saw, a concrete saw, or a track saw. The manufacturer claims that a sawed cut made ¼ the slab depth provides a plane of weakness for fast break out and removal and that openings are made to exact size, saving up to 30 per cent on replacement material.

Clipper Concrete Saws. Clipper Manufacturing Co., 2800 Warwick, Kansas City 8, Missouri.

Pipe and bolt threading machine

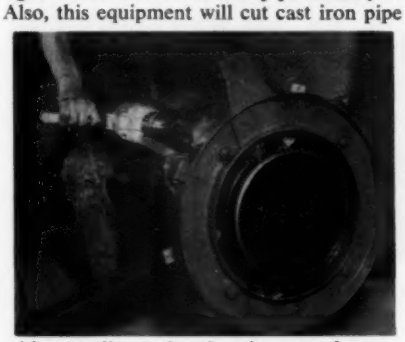
This pipe and bolt threading machine includes a new type of self-contained die head said to reduce cost and make notable savings of work and time. The new head is instantly adjustable to thread 1″ to 2″ pipe, including over and under size, regardless of position of quick-opening lever and without removing dies or die head from the machine. The improved heads, one for ¼″ and ⅜″ and one for ½″ and ¾″, offer this same instant size change in the machine. Heads for ⅛″ to 2″, and bolt die heads, ¼″ to 2″, also are available. All tools cut and ream independently, close to the chuck, and swing up out of the way when not in use. Thread oil system is entirely concealed. Thread and length gauge has large numerals. Chuck has six adjusting pinions. Motor supplies ample power even for pipe to 12″ when geared tools are used, is forward-reverse, 115 volts, 25 to 60 cycles, AC or DC, single phase.



Ridgid 500 Threading Machine. The Ridge Co., Elyria, O.

Portable pipe cutter

A new portable pipe cutter has been designed to cut and bevel steel pipe on the job. Also, this equipment will cut cast iron pipe



without splits or breaks, the manufacturer states. The equipment is light weight and provides flexible features for using it on pipe already installed. Claims are made for true cuts with flat edges on the inner circumference, ready for welding. Two models cover the range of pipe from 6″ to 16″. The smaller model weighs approximately 60 pounds. It can be slipped under pipe already in the ground. Power can be taken from a ¾″ slow-speed electric drill, the equivalent in an air drill or a flexible shaft on a gasoline motor geared to slow speed. Adaptability to gas construction and maintenance work is noted by the manufacturer. Another advantage claimed is that pipe already in a ditch can be cut exactly where wanted, with only 1/3 as much ditching as necessary to make the cut and replacement. The cutter is made with a cast aluminum housing. Ball bearings are sealed on eccentric fittings for adjustment. The manufacturer claims the tool increases its depth of cut with every revolution and compensates for out-of-round pipe. It is held firmly in position on the pipe during the cutting. Replaceable cutter bits are of high-speed steel. Oiling of the cut is automatic.

SpringLoad pipe cutter. SpringLoad Manufacturing Corp., 2412 Aurora, Seattle 9, Wash.

MISCELLANEOUS

Caulking material conditioner

A compound of oils and other ingredients is being made for the swelling of jute, hemp, rope and other yarns, to counteract the leakage in bell and spigot joints caused by the shrinkage of these caulking materials when dry natural gas replaces manufactured gas. It is claimed that this material will return to the jute the moisture and natural oils necessary to maintain the original size of the jute. The manufacturer states as technical features that the material is safe to handle, identifying color makes it easily traceable, and elimination of clamping costs.

Sealall. Gas Purifying Materials Company, Inc., 3-15 26th Ave., Long Island City, N. Y.

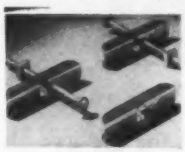
Main flushing mixture

A non-acidic mixture of wetting and detergent agents is available for wetting large dust deposits at bottoms of gas mains. Claims are that this concentrated material, diluted with water, will wet the dust deposit in the main, but will not disturb it. Flushing with water will wash the dust deposit to the nearest drip while the main still remains in service. The chemical properties of this material are said to be non-injurious to the skin and non-corrosive.

Flushall. Gas Purifying Materials Company, Inc., 3-15 26th Ave., Long Island City, N. Y.

Three-in-one toggle bolt assembly

A new type toggle bolt may be installed with either (1) the head of the bolt outside the wall or (2) with the nut outside the wall and (3) the toggles may be purchased separately and used with any bolt. The toggle head is available from stock for bolt diameters from ⅛″ to ½″.



Super Grip 3-in-1 Toggle Bolts. Super-Grip Anchor Bolt Co., Inc., 3333 N. 22nd St., Philadelphia 40, Pa.

Hot fogging oils

For hot fogging, this manufacturer offers a formulation of oils to lay dust particles suspended in gas, to wet and lay dust and deposited contaminents on the walls of mains, and to prevent drying out of meter diaphragms and jute in bell and spigot joints. This fogging oil is custom made, taking into consideration the factors for individual distribution systems: map of the distribution system, locating foggers and drips; type of fogger; temperature of sweep gas; velocity of gas in transmission lines; length and diameter of main to be treated; number of regulators. The manufacturer claims the material is non-corrosive, and that its identifying color acts as a penetration tracer.

Fogall H. Gas Purifying Materials Company, Inc., 3-15 26th Ave., Long Island City, N. Y.

Balanced vault cover

Designed for safe and easy operation, opening of this counterbalanced vault or manhole cover is accomplished by combination key handle. Lifting the cover to its vertical, open position is a one-hand job. Counterweights, which also hold the cover in a protective upright position, ease the load. Other features are (1) cover can not slam or drop into vault, (2) cover can be opened from inside by one man, (3) positive tamper proof lock can not be opened from outside without key-handle, (4) counterbalance protrudes less than 6″ from wall, (5) 30″ square opening, (6) heavy duty cast iron frame and ribbed steel cover machined for accurate fit, (7) rattle proof, (8) oilite bronze bushings in linkage. Applications: valve, meter, transformer, district governor vaults or other underground vaults of municipalities, utilities, manufacturing plants.

Wachs Safety Manhole Cover. The E. H. Wachs Co., 1527 N. Dayton St., Chicago 22.

Metallic joint sealing compound

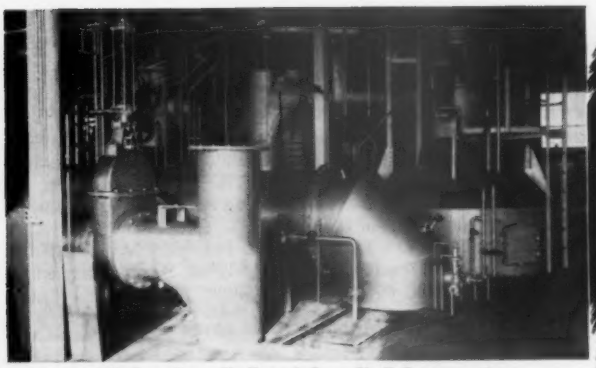
The manufacturer of a new sealing compound claims easier removal of clean-out plugs and that it serves as an anti-seize coating. It is described as a pure metallic lead pipe thread lubricant and sealer which is free of drying agents and is claimed to be impervious to air, water, steam, oils, ammonia and hydro-carbons. The temperature range is from —100 to 2,987°F.

Compound 411. Armite Laboratories, 6609 Broad St., Los Angeles 1.

Cleaning gas meter exteriors

A new method of removing grease, oil stains and other dirt from the exteriors of household and other gas meters, prior to dismantling and rebuilding, has been announced. A dip-cleaning machine augments the chemical action of a cleaning solution by up-and-down movement at the rate of fifty times a minute. The solution, a mildly alkaline cleaner with added wetting action, is made up in water, two ounces per gallon; charged into the machine and heated to 120°F. Five to eight meters are loaded in the work basket for a two-minute cleaning action. They are then placed in warm water rinse tank and moved to the dismantling station. Intake and exhaust openings are capped during this cleaning operation. The solution has a softening effect on the exterior meter paint. The paint rehardens, it is said, by the time the meters reach the repair station. Where removal of paint is desired, a suitable paint stripper can be used in the machine.

Magnus Aja-Dip Cleaning Machine, Magnus 1DX Cleaning Solution. Magnus Chemical Co., Garwood, N. J.



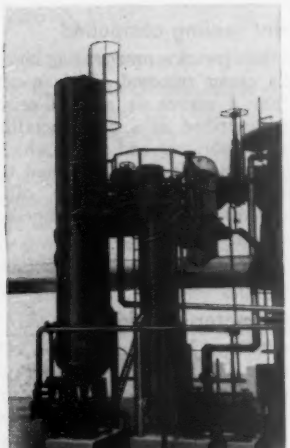
Oil Gas. Two Shell and Four Shell Regenerative Sets. Conversion of Water Gas Sets to Twin Generator or Single Burner Type.

WHATEVER YOUR GAS PLANT REQUIRES...

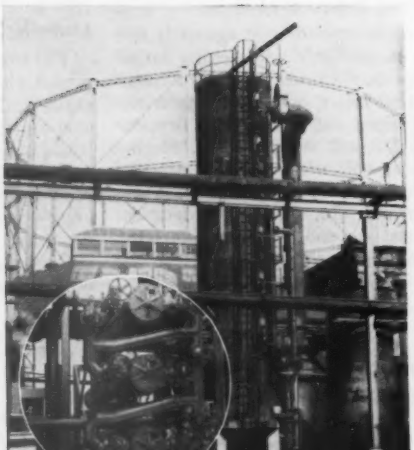
GASMACO HAS IT!

Oil Scrubbing and Light Oil Recovery Apparatus.

Iron Oxide Purifiers with Valve Manifold and Cover Lifting Crane. Also built in high pressure design.



Tar Dehydration Equipment.



Cooling Scrubbers, Multiple Spray Type, with Gas Liquor Coolers.

Automatic Controls, Gauge Boards, and accessories.

GASMACO has these and many other items for the gas plant, such as equipment and processes for thermal or catalytic cracking of hydrocarbon feeds and for liquefaction, storage and regasification of natural gas.

Call or write for a list of GASMACO's complete line of equipment and services. Our engineers will be pleased to review your requirements and to prepare special designs if needed.

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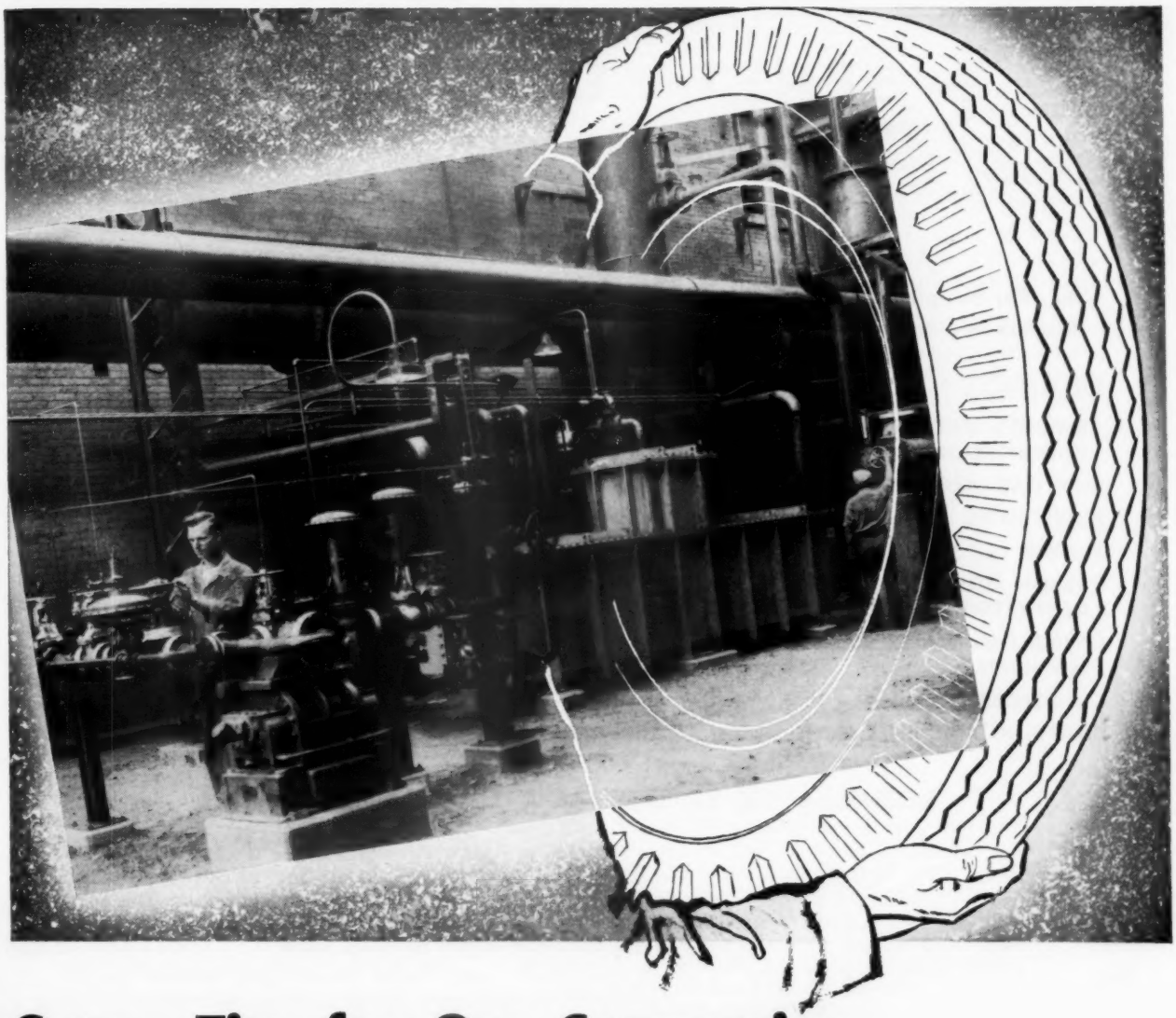
HAMILTON, ONTARIO



Spare Tire for Gas Companies

• Koppers now has available a furnace for producing gas from fluid hydrocarbons, gaseous and liquid—the Koppers-Hasche Furnace. It is a spare tire for the utilities which distribute natural gas and industrial plants which use natural gas. That's because it can produce manufactured gas and pinch hit in the event of temporary failure of the natural gas supply.

Further, manufactured gas made by the Hasche Furnace *mixes readily* with natural gas. Therefore, during peak-load periods, utility companies can add this manufactured gas and keep their supply up to demand.

This new gas-producing plant isn't limited to standby service. Companies can convert from carbureted water gas or coal gas to Hasche Reformed Gas — *without* the tremendous cost of changing customers' appliances. Also, by using the Hasche Furnace, smaller gas companies can produce gas at a cost comparable to the larger gas companies.

The investment cost of the Koppers-Hasche Furnace is low — lower than that of any other equipment for producing manufactured gas. Operating cost is also low; efficiency is high. Write to us for full information on the Hasche Furnace.

KOPPERS

KOPPERS COMPANY, INC.

Engineering and Construction Division, Pittsburgh 19, Pa.

SEMET-SOLVAY ENGINEERING DIVISION

40 RECTOR ST., NEW YORK 6, N.Y.

ALLIED CHEMICAL & DYE CORPORATION

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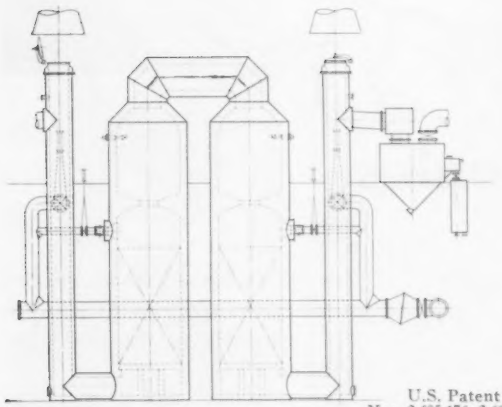
AMMONIA RECOVERY and CONCENTRATION APPARATUS
BLUE GAS MACHINES
BLAST GATES
BUNKER "C" OIL SYSTEMS
CARBON MONOXIDE GENERATING PLANTS
CARBURETED WATER GAS MACHINES
CONDENSERS (Tubular)
CHARGING MACHINES (Fuel)
COOLING COILS
DE-EMULSIFIERS
FUEL HANDLING SYSTEMS
HEAT EXCHANGERS
HIGH BTU OIL GAS MACHINES
LIGHT OIL RECOVERY PLANTS
MECHANICAL GRATES
MULTIPLE WASHERS
PIPE and FITTINGS (Welded)
PRODUCER GAS PLANTS (COKE, BITUMINOUS COAL, or ANTHRACITE)
PURIFIERS and TRAYS
SCRUBBERS and GRIDS
STEAM ACCUMULATORS (L.P. type)
TAR CAMERAS
TAR EXTRACTORS
TAR BURNING EQUIPMENT
WASHER COOLERS
WASTE HEAT BOILERS
VALVES (Hydraulic and Hand Operated)
VALVES (Three-way)

REGENERATIVE REVERSE FLOW OIL GAS MACHINE



U.S. Patent Nos. 2,605,176, 2,605,177

1 Make oil is injected downward in the reactor. It is sprayed Counter-Current to the ascending flow of carrier gas which entered the checkerless reactor through an aperture. This aperture develops enough velocity to prevent the passage of oil vapors or carbon into the space below.

2 Make gas descends through the gas fixing chamber insuring controlled heating of gas for fixing the oil gas vapors.

3 A substantial portion of the oil gas is then rerun through the reactor. With steam added it's called "carrier gas" and this drives the gas through the machine.

4 During the make period carbonaceous material deposits on the gas fixing chamber checkers and reactor walls. It burns and regenerators absorb the heat from this and the oil burner. This stored heat is passed on to primary air and uprun carrier gas by the regenerator.

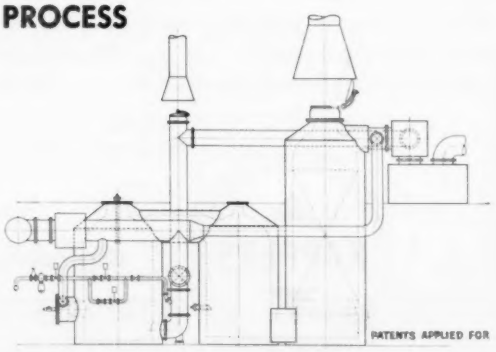
5 These products of combustion descend through the reactor and checkered chamber while the gases requiring preheat ascend, which principle conforms to the physical laws of efficient regenerator operation.

POUGHKEEPSIE OIL GAS PROCESS

1. What is the Poughkeepsie Oil Gas Process?
It is a simplified type of conversion starting with your existing three-shell carbureted water gas machine.

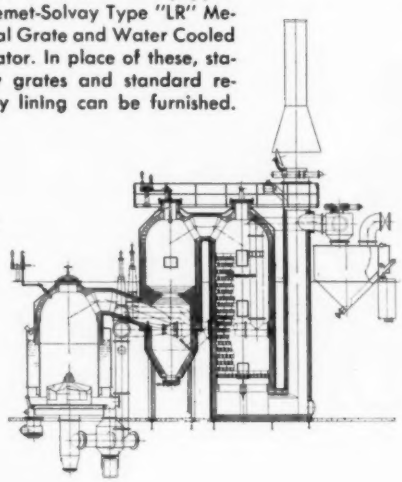
2. What are its uses?
This process has been designed primarily for peak load shaving and standby gas purposes The gas is readily interchangeable with natural gas.

3. Is it an adaptable process?
Certainly. It was originally planned for gas oil operation, but with the back blast connection as shown, heavier grades of oil may be used.



REVERSE FLOW WATER GAS MACHINE

Machine illustrated is equipped with Semet-Solvay Type "LR" Mechanical Grate and Water Cooled Generator. In place of these, stationary grates and standard refractory lining can be furnished.



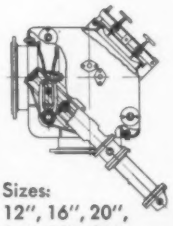
In the Semet-Solvay Reverse Flow Water Gas Machine, the mixture of blue gas and oil gas produced on the uprun passes up through the carburetor and down through the superheater, thus reversing the direction of flow of both backrun steam and uprun gases as found in the standard three shell water gas machine.

This design provides the greatest flexibility in fuel and oil requirements, the relative quantities of which can be varied through a wide range to take advantage of market conditions. In addition, it is adaptable to the use of coke, anthracite and bituminous coal or mixtures of these fuels.

The upflow checkerless carburetor, with its distributing orifice at the bottom, assures true counter-current contact between the ascending blue gas and the descending enriching oil. This results in extremely efficient vaporization of the oil, so that it is never necessary to shut down the machine due to carbon deposits in the carburetor.

THREE-WAY VALVE

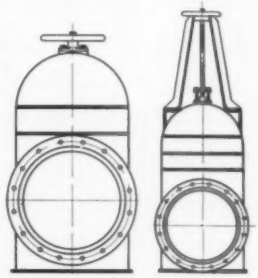
The Semet-Solvay three-way valve is constructed of steel plate and is provided with two inlet nozzles and one outlet nozzle. Discs mounted on an internal vertical shaft are actuated by a hydraulic cylinder so that one inlet is closed when the opposite inlet is open. Outlet from the valve is always open. Internal sprays provided to prevent accumulation of dust or other impurities.



Sizes: 12", 16", 20", 24", 30", 36" and 42".

BLAST GATES

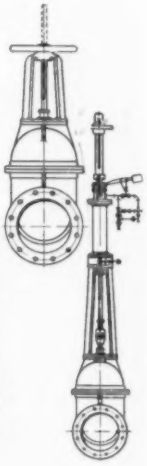
Semet-Solvay steel blast gates are light in weight and are easily welded or bolted to existing lines. They are suitable for use at pressures from 4 to 6 psi, and can be furnished for either handwheel or chainwheel operation. The standard blast gate is suited for use on air only since there is no stuffing box at the stem. When handling gases or wherever leakage is objectionable, gates can be furnished with a stuffing box at the stem and with set screws to provide tight closure of the disc. Either type may be had in standard sizes from 6" to 60". Larger sizes furnished to special order.



GATE VALVES

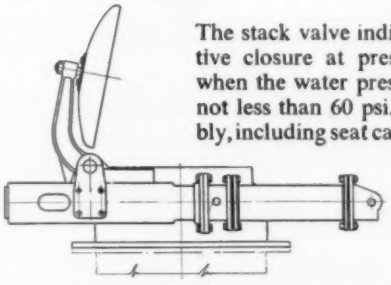
Semet-Solvay all iron, double disc gate valves are suitable for handling air or gas at the following pressures:

Size	Working Pressure
4" to 8"	50 psi
10" to 16"	35 psi
20" to 36"	25 psi



They can be furnished with flanges conforming to any of the usual standards or with bell and spigot ends, and for handwheel, gear, chainwheel or hydraulic operation. The hydraulically operated valves are especially useful in controlling the flow of air or gas in cyclic operations since they not only provide a positive shutoff, but also furnish a convenient means of adjusting the rate of flow to varying demands during the cycle of operation.

STACK VALVE



The stack valve indicated provides a positive closure at pressures up to 60" wg, when the water pressure at the cylinder is not less than 60 psi. The complete assembly, including seat casting, can be furnished for attaching to your superheater.

Sizes: 14", 18", 24", 30", 36", and 42.".

SEMET-SOLVAY ENGINEERING DIVISION
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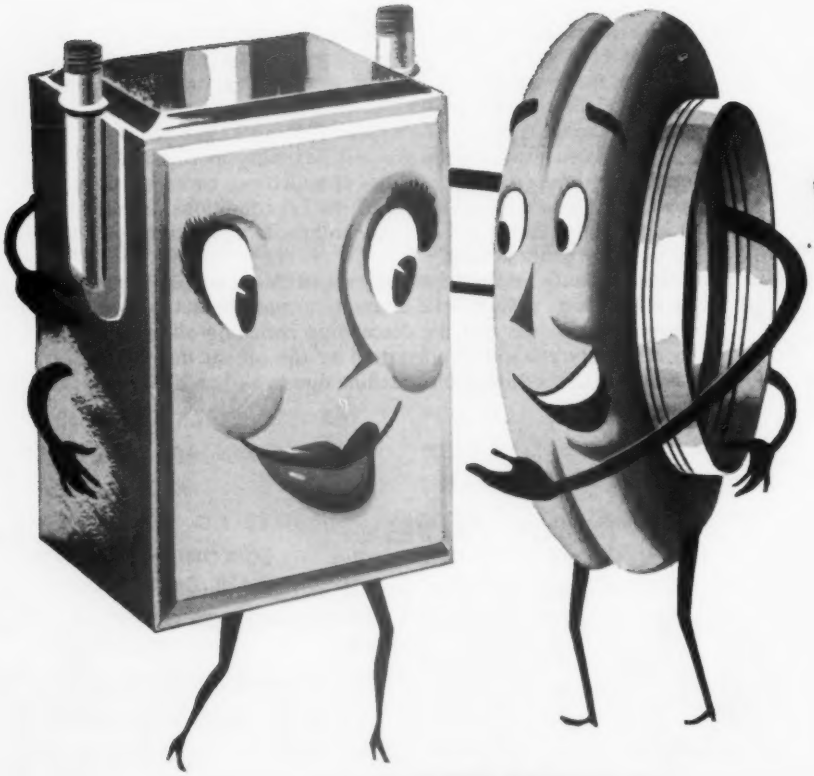

PARTNERS FOR LIFE!

VULCAN DIAPHRAGMS

VULCAN Diaphragms in meters, regulators and controls should serve faithfully for a long and accurate service life.

Why waste time and money on diaphragm replacements?

Why waste time and money on periodic oiling of diaphragms?

VULCAN Diaphragms are scientifically made for utmost strength, perfect pliability. They remain tough yet supple and sensitive year after year in the most exacting service. They contain no oil, yet never need oiling. They work in bone dry gas or at 100% saturation, in all types of gases. They repel gums and condensates... never dry out and stiffen.

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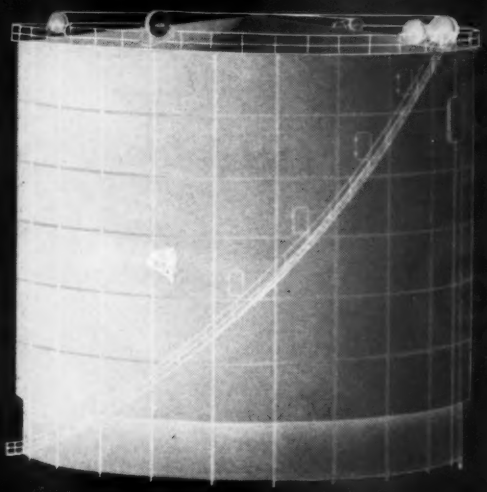
Wiggins Gasholder



the **only** gasholder that uses

NO WATER
TAR
GREASE

the **only** gasholder that assures

NO WEATHER WORRIES
OPERATING COSTS
MAINTENANCE PROBLEMS

the **only** gasholder with **AN ABSOLUTELY DRY, FRICTIONLESS SEAL**

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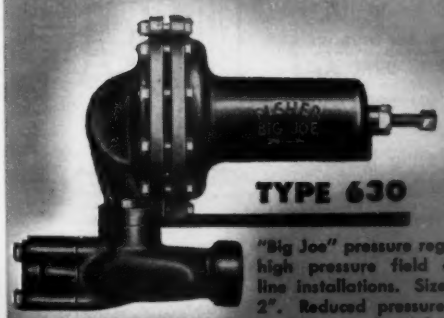
The Industry's *Most Complete* Line of GAS REGULATORS

TYPE 99

Self-contained pilot operated gas regulator for small border stations and industrial applications. 2" size only. Reduced pressure range 4 oz. to 65 lbs.

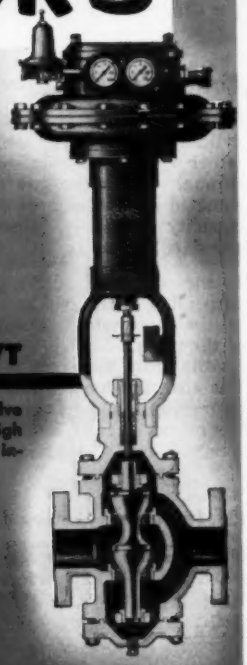
Fisher Governor Company's wide variety of regulators handle control applications ranging from the natural gas well head to burner utilization. Illustrated are just a few of the varieties of construction.

This complete Fisher line of regulators for the gas industry includes District Regulators, high, low and intermediate pressure — Distribution Regulators — House Service Regulators — High Pressure Field Regulators — Boiler Gas Fuel Governors — Booster Regulators — Safety Shut-Off Regulators — Town Border Station Regulators — Industrial Gas Regulators — Meter Run Regulators.



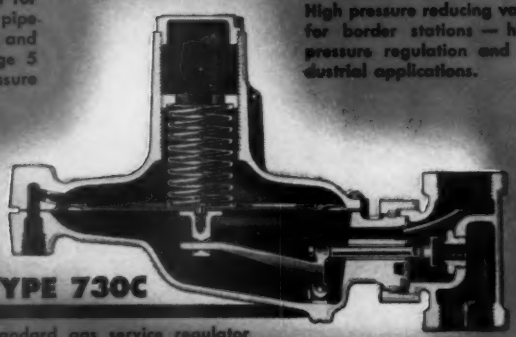
TYPE 630

"Big Joe" pressure regulator for high pressure field and pipeline installations. Sizes 1" and 2". Reduced pressure range 5 to 200 pounds. Inlet pressure up to 1000 lbs.



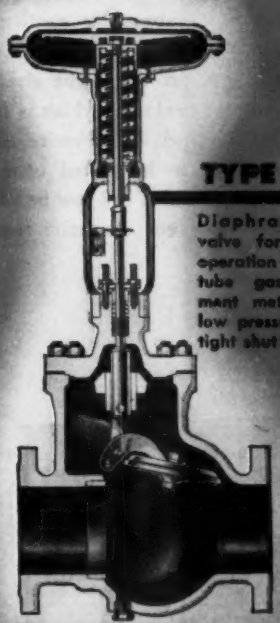
TYPE 4100D-57T

High pressure reducing valve for border stations — high pressure regulation and industrial applications.



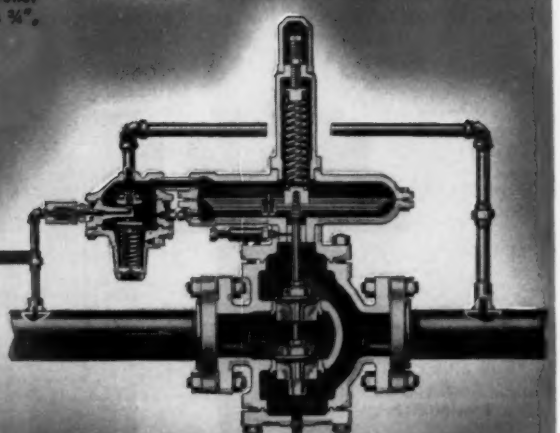
TYPE 730C

Standard gas service regulator with or without integral relief valve, bug-proof vent. Sizes ¾", 1", 1¼", and 2".



TYPE 57T-L

Diaphragm motor valve for automatic operation of multiple tube gas measurement meter runs — low pressure drop — tight shut off.



TYPE 298

Pilot operated gas pressure regulator — non-bleed construction — for border station and district regulator applications, for low and intermediate pressures. Sizes 2" and up.

FISHER GOVERNOR COMPANY • Marshalltown, Iowa

FISHER® LEADS THE INDUSTRY IN RESEARCH FOR BETTER GAS PRESSURE CONTROL

RESEARCH CORPORATION

Plant: Bound Brook, New Jersey

New York Office: 405 Lexington Ave., N. Y. 17, N. Y. *Chicago Office: 122 So. Michigan Ave., Chicago, Ill.*

The COTTRELL PROCESS of Electrical Precipitation for Detarring Manufactured Gas

Cottrell Electrical Precipitation Equipment has established itself by its successful performance record in the Gas Industry as a standard means of detarring gas which claims the confidence of engineers and executives seeking maximum results at minimum costs. Over 300 installations of this equipment are in use in carburetted water gas plants and by-product coke oven gas plants handling a total of over 3½ billion cubic feet of gas per day.

Equipment Used for Detarring

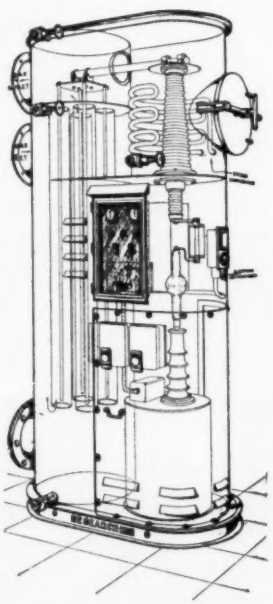
The precipitator for this service is usually constructed with a cylindrical shell in which are grouped collecting electrode pipes either 6″ or 8″ in diameter, depending upon the size of the unit, through which the gas passes. These precipitators are constructed in a number of different sizes so that any gas cleaning capacity may be obtained by utilizing one or more of these standard size units.

In the operation of the precipitator, the tar and oil, which is suspended in the gas as a fog or mist, is driven out of the gas by the electrostatic action and collects on the inside surfaces of the pipes. The collected tar and oil being free flowing, flows readily from the pipes so that the precipitator is self cleaning. The electrical power consumed in the operation of the precipitator is small, averaging 5 to 8 Kw hours per million cubic feet of gas cleaned, and the pressure drop across the precipitator is only ¼″ to ½″ H_2O.

Carburetted Water Gas

In carburetted water gas plants the precipitator is usually located after the exhausters so that the gas is handled at a pressure range from 1″ to 3″ Hg and at a temperature range from 70°F. to 125°F. at the inlet to the precipitator. Actual tests show removals ranging from 95 to 99% of the tar, oil and entrained water with a pressure drop of less than a quarter of an inch of water across the precipitator. This effective tar removal has greatly improved and reduced the cost of subsequent gas purification. Where dry purification is used the elimination of the tar ahead of the purifier has increased the sulphur conversion, reduced the fouling of the oxide and eliminated caking of the beds.

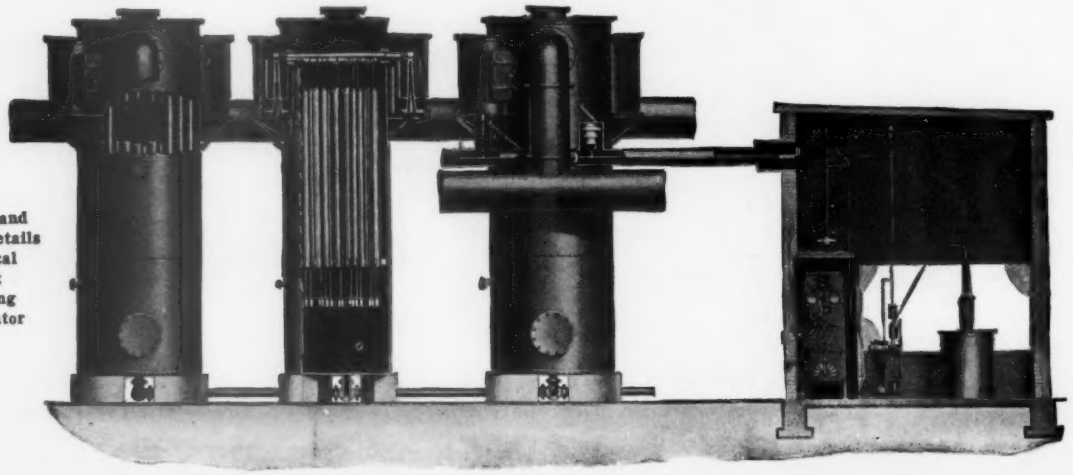
By-Product Coke Oven Gas



The precipitators for coke oven gas in some instances are located ahead of the exhausters while in other instances they are located after the exhausters so that pressure at which the gas is treated will range from 1″ Hg suction to 3″ Hg pressure. In all cases the precipitator follows coolers so that temperature ranges from 70°F. to 125°F. These units show tar removals ranging from 95 to 99%. As a result there is less contamination of the sulphate, less fouling of the circulating liquor in the light oil recovery towers, and less difficulty in the distribution and utilization of the gas.

Small Gas Plants

A Cottrell Precipitator Unit (shown above) is particularly suited for the small gas plants with capacities ranging from 500,000 to 2,500,000 cubic feet of gas per day. The electrical equipment for this unit is placed in a steel shell which is fabricated integrally with the precipitator shell. The entire unit is shipped completely assembled ready to be placed upon the foundations. As a result Cottrell Equipment can now be offered that will satisfy the space limitations and economic requirements of the small gas plant.



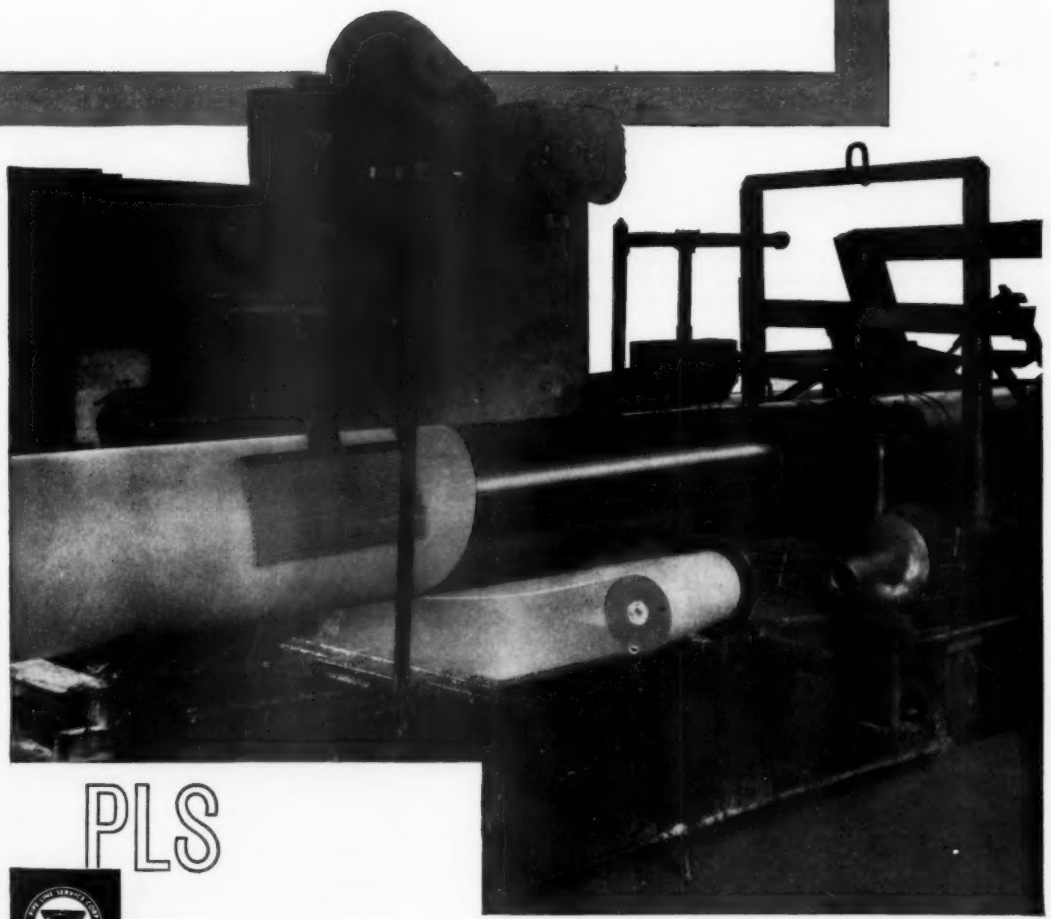
Exterior and Interior Details of Typical 3 Unit Detarring Precipitator

How PRECISION EQUIPMENT Gives You More For Your Money in PLS Controlled Pipe Protection

Nothing is left to chance at Pipe Line Service to give customers uniform, high quality pipe protection. All equipment used has been developed by PLS engineers for maximum efficiency and economy in cleaning, priming, coating and wrapping.

Typical of the precision techniques employed is the coating and wrapping operation illustrated here. The pipe is propelled by positive-drive units which control the forward spiral movement of the pipe through the coating machine. This insures *uniform* lap of wrappers at all times.

Precision equipment like this is operated by trained personnel *inside* our plants to avoid delays caused by weather conditions. These factors add up to PLS *controlled* service which gives you more for your money in pipe protection.



PLS

PIPE LINE SERVICE CORPORATION

General Offices and Plant • Franklin Park, Ill.

PLANTS AT: GLENWILLARD, PENNSYLVANIA; LONGVIEW, TEXAS; CORPUS CHRISTI, TEXAS; HARVEY, LOUISIANA; SPARROWS POINT, MARYLAND

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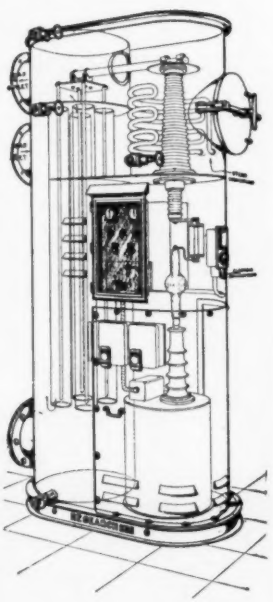

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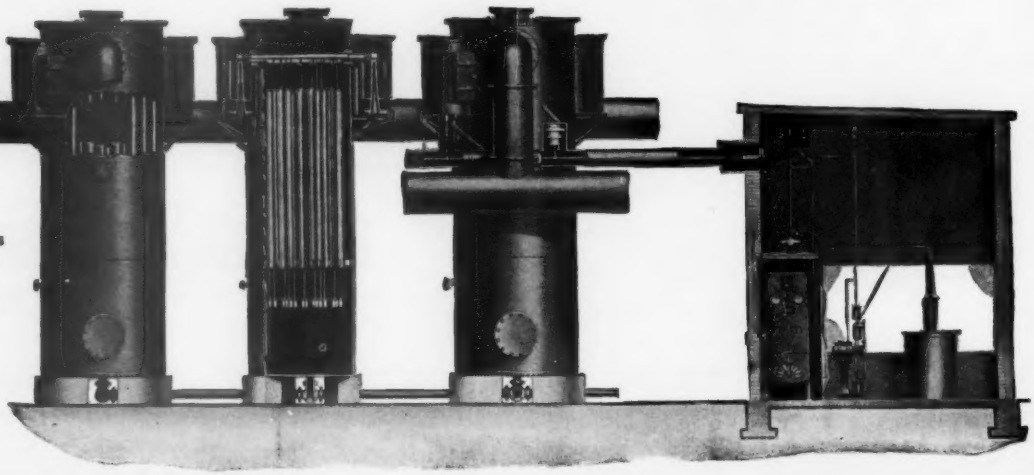

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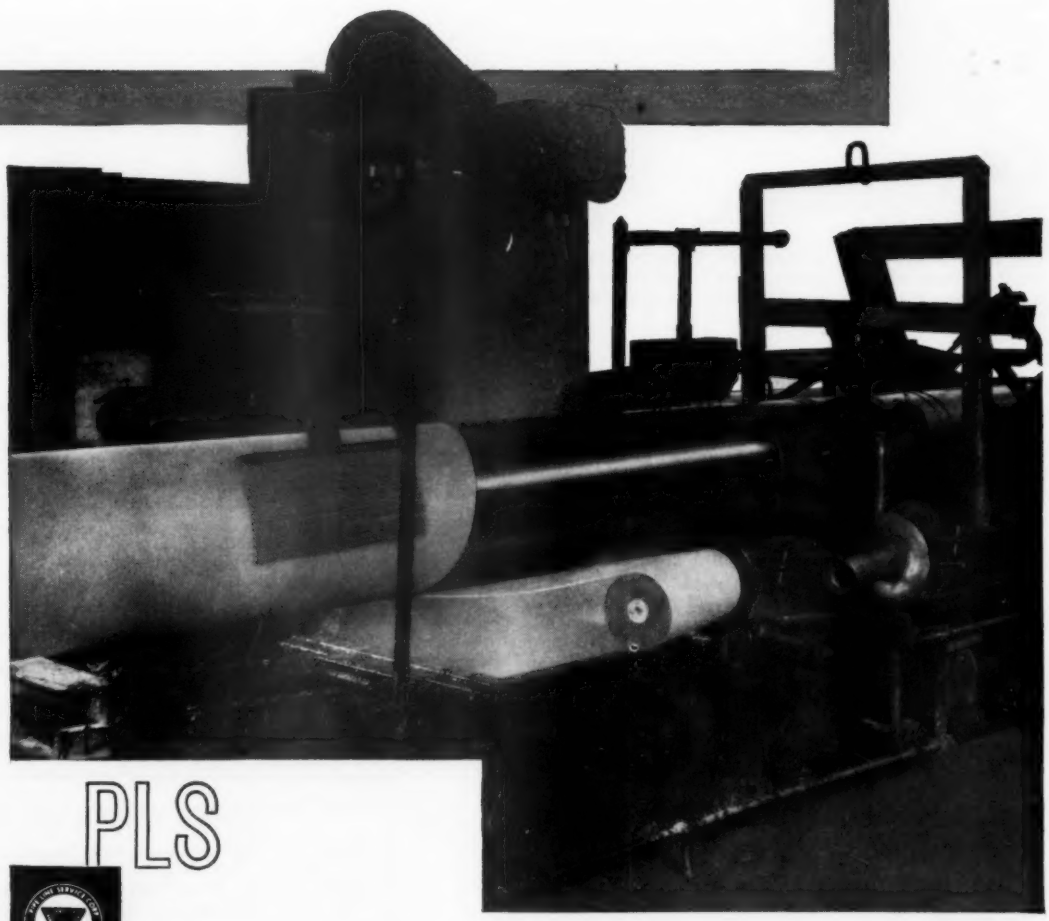

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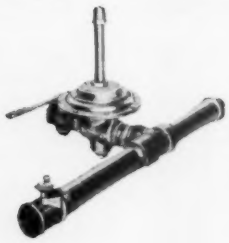
HAUCK MANUFACTURING CO.

142-152 TENTH STREET, BROOKLYN 15, N. Y.

Sales Engineering Offices in Boston, Chicago, Cleveland, Philadelphia, Pittsburgh and San Francisco. Representatives in Other Principal Cities

Manufacturers of Gas and Oil Burners and Equipment for Industrial Furnaces, Ovens, Air Heaters, Boilers, etc.—Combustion Engineers



Low Pressure Air-Gas Proportional Mixers

Made for single valve control with automatic proportioning of air and gas to any desired ratio. Ideal for manual or automatic firing control applications. Catalog 805.

High Pressure Gas-Air Inspirators

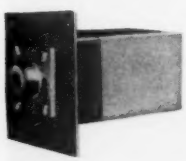
Utilize gas at 1 to 30 lbs. pressure to inspirate the air required for combustion. Wide range of gas capacity with constant gas-air ratio is obtained merely by controlling the gas pressure with a single valve. Catalog 806.

High Pressure Air-Gas Boosters

For high temperature applications with low pressure gas. Use small amount of high pressure air to inspirate atmospheric air, mixing the air and gas simultaneously. Catalog 806.

Sealed-in Gas Burner Nozzles

For installations requiring a constant atmospheric condition, these nozzles provide high combustion efficiency. Eliminate uncontrolled air infiltration and induced air at the nozzle outlet. Catalog 804-D.

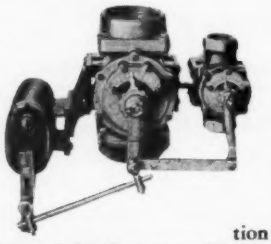


Tunnel Gas Burners

Assembled units of sealed-in burner nozzle, refractory combustion tunnel and burner mounting box. Eliminate ramming of refractory tunnels; easy to install; equipped with openings for pilot lighting and flame rod. Available with or without mounting flange. Catalog 804-D.

"Retain-a-Flame" Burner Nozzles

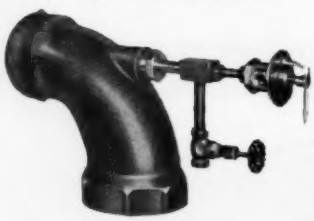
For blast firing gas mixtures into an open port or without a combustion chamber, Hauck "Retain-a-Flame" Nozzles, straight or elbow types, operate with minimum turbulence in main stream for long, cylindrical torch flames. Catalog 804-C.



Adjustable Flow Valves

Permit infinite variety and range of flow curves for controlling gas or air at any 10 adjusting points, to suit different constants in pressure, suction or discharge, at any capacity. Made in straight thru or angle types. Valve may be used singly or in dual or multiple interlocked arrangements, for automatic control. Shown are dual assembly with control motor and a single straight thru type valve with snap connection. Catalog 713.

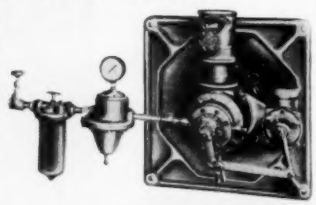
Oil Atomizing Inserts for Gas Burners

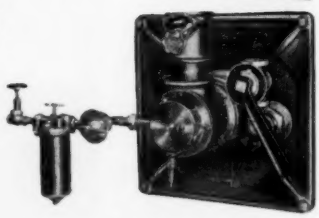


For standby firing with oil, when gas is in short supply. Easily installed in nozzles or tees of many high or low pressure gas burners. Equipped with self-clean metering, micro-control oil valve. At left—Insert installed in Hauck elbow type, "Retain-a-Flame" gas burner nozzle. Catalog 715.

Combination Gas and Oil Burners

Burn either fuel with equally good combustion and efficiency in a wide range of capacity. Instant switching of fuels without any changing of burner parts or piping. Single lever regulates and automatically proportions the flow of both air and gas or oil. Burners also available with individual control valves for fuel and air. Catalog 408-A.





OTHER HAUCK PRODUCTS

Low and High Pressure Oil Burners, Micro-Control Oil Valves, Fuel Oil Heaters and Preheaters, Burner Mounting Plates and Brackets, Pumps, Oil Strainers, Automatic Shut-Off Valves, Oil Heaters, Temperature Regulators, Thermometers and Pressure Relief Valves. Oil or Gas Torch Burner Equipments of all types for heating and repair work, lighting coal fires, melting, thawing, etc. Melting Kettles for tar, asphalt, lead, compound, etc.

Hauck subscribes to the GAMA Industrial Division's Code of Ethics

Tennessee River Gas Line goes down to stay!

Universal *concrete river weights* (reinforced concrete clamps) hold down two 22-inch gas lines across this 1300-foot span of the Tennessee River. Most of the work was completed ashore on small dollies running on a narrow-gauge track. The line was then "floated" across the river (submerged 3 to 5 feet) and lowered into a trench on the river bottom. This project was handled by the contractors and engineers for the Texas Gas Transmission Corporation of Owensboro, Kentucky.

Universal *river weights* are made of reinforced concrete in two half-round sections. They are available in sizes for 12-inch-diameter pipe and larger. A river weight for a 26-inch-diameter pipe, *for example*, weighs 1966 pounds in air, 1107 pounds in water. Each river-weight section has a 6-inch lifting hole, with a ¾-inch steel hook, for easy lifting by crane. Four bolts clamp the river weight to the pipe.

A two-color, four-page folder gives you more details on this particular project. Write the *home office* or the Universal office nearest you: ALABAMA: Decatur, Dothan, Florence. FLORIDA: Miami, Ocala (Florida Concrete Pipe Co.), St. Petersburg, Tallahassee, Tampa. GEORGIA: Atlanta. KENTUCKY: Louisville (Dixie Concrete Pipe Co.). MARYLAND: Baltimore (Jessups). NEW JERSEY: Kenvil. NEW YORK: Binghamton, New York City, Port Washington, Rochester, Syracuse. OHIO: Columbus, Zanesville. PENNSYLVANIA: Norristown, Pittsburgh. TENNESSEE: Nashville. WEST VIRGINIA: Clarksburg, Charleston, New Martinsville, Wheeling. AFFILIATE—Concrete Pipe Co. of Ohio, Cleveland, Sandusky, Youngstown, Ohio; and Erie, Pa.

Universal
Concrete Pipe Company
RIVER WEIGHTS
Home Office: 297 S. High St., Columbus 15, Ohio

SAFETY GAS MAIN STOPPER CO.

STREET DEPARTMENT

523 Atlantic Avenue, Brooklyn 17, N. Y.
Cable Address: Gastopper, New York

GOODMAN — USED SINCE 1897 — 2" HANDLE & LOCKING SLEEVE — GAS MAIN STOPPER

SUPPLIES

Pac. Coast Rep.: C. B. Babcock Co., 384-7th St., San Francisco 3, California

New England Rep.: Eastern Appliance Co., 281 Vassar St., Cambridge 39, Mass.

GOODMAN IMPROVED GAS MAIN STOPPER

Patented

The Reliable Shut-off for Street Mains. Now has as its newest feature the "Z" Handle for easier manipulation. The Locking Sleeve (at right) holds the Stopper firmly in place. When locked in place it holds. Takes only 30 seconds. LOOK FOR THE NAME GOODMAN.

Sizes 3" to 48"

Patented Improved Locking Sleeve

GARDNER-GOODMAN STOPPER

Patented

A stopper for low and intermediate pressures.

For use on cast iron or steel, oversize or undersize mains.

Easily inserted in top, bottom or side of main, in open excavation or under pavements.

For pressure work, use two or more stoppers in parallel.

Sizes, 2 inch to 20 inch.

DEPENDABLE GAS MAIN BAGS

PLAIN RUBBER

CANVAS COVERED

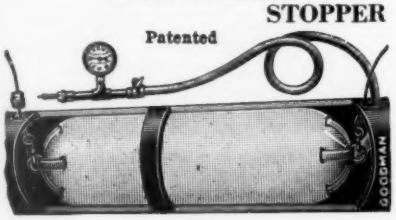
Type C

For the present, we have discontinued the manufacture of all types of bags except Type "B" Plain Rubber (medium weight) and Type "C" Canvas Covered Bags.

Type "C" for use in mains coated with tar or oil and wherever a plain rubber bag would not hold. This canvas-covered bag consists of an inner bag of fine quality rubber, strong and expansible, encased in a cover made of best quality U. S. Army duck. **Gauge of Rubber** and **strength of duck suited to each size.** Bags correctly fashioned and covers finely tailored insure a snug fit and a good shut-off when the bag is inflated in the pipe. Fitted with tire valve, nipple, hose clamp and thumb screw. **Inflate** as you would a tire. **To deflate** pull out the **valve.**

GOODMAN CYLINDRICAL STOPPER

Patented



This is an inflatable bag with a fine, strong waterproof casing for use in gas and oil pipes. The broad central zone making contact with the wall of the pipe keeps the bag from creeping or slipping.

It may be inflated to a high internal pressure and will hold against 60% as much pressure in the main.

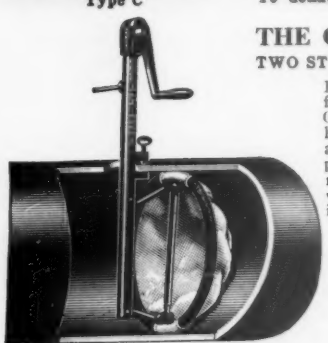
This stopper is pulled into place by cables. It will hold back more pressure than any other bag.

Sizes, 2 inch to 48 inch in stock.

Special sizes to order.

THE GOODMAN-PEDEN STOPPER

TWO STYLES—WITH OR WITHOUT PLUG



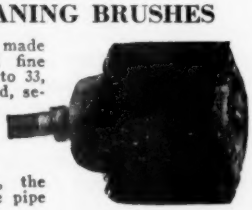
Patented

In the Goodman-Peden Stopper the flexible frame, padding, covering and diaphragm of Goodman Stopper remain in principle, but the handles have been discarded and in their stead a new arrangement in construction makes it possible to operate the stopper mechanically rather than by the experience and skill of the workman. Made in standard sizes.

TAPE FOR EMERGENCY REPAIRS

A valuable aid to have on hand to bandage up breaks in mains and services. Repairs made this way will hold for long periods if necessary. Bandage with Soap Tape and cover with Binding Tape Strips 2", 4", 6", 8".

PIPE CLEANING BRUSHES



Sizes 10" to 24", made from Bassine and fine steel wire, No. 39 to 33, or heavier if needed, securely mounted in a hardwood ring which is held in place by galvanized steel discs. The wire scrapes, the Bassine sweeps the pipe clean.

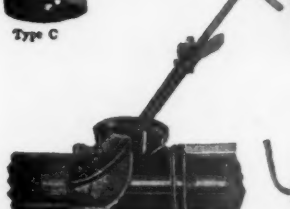
Sizes 3" to 8".

PLUGS FOR SPECIAL USES

ALL KINDS OF PLUGS

Type No. 5

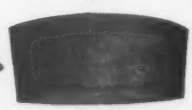
Type C



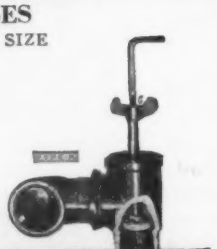
Type No. 6

ANY SIZE

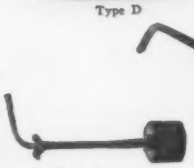
Type B



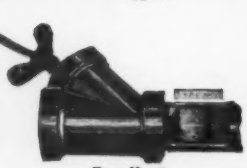
Type D



Type A



Type A



Type No. 7

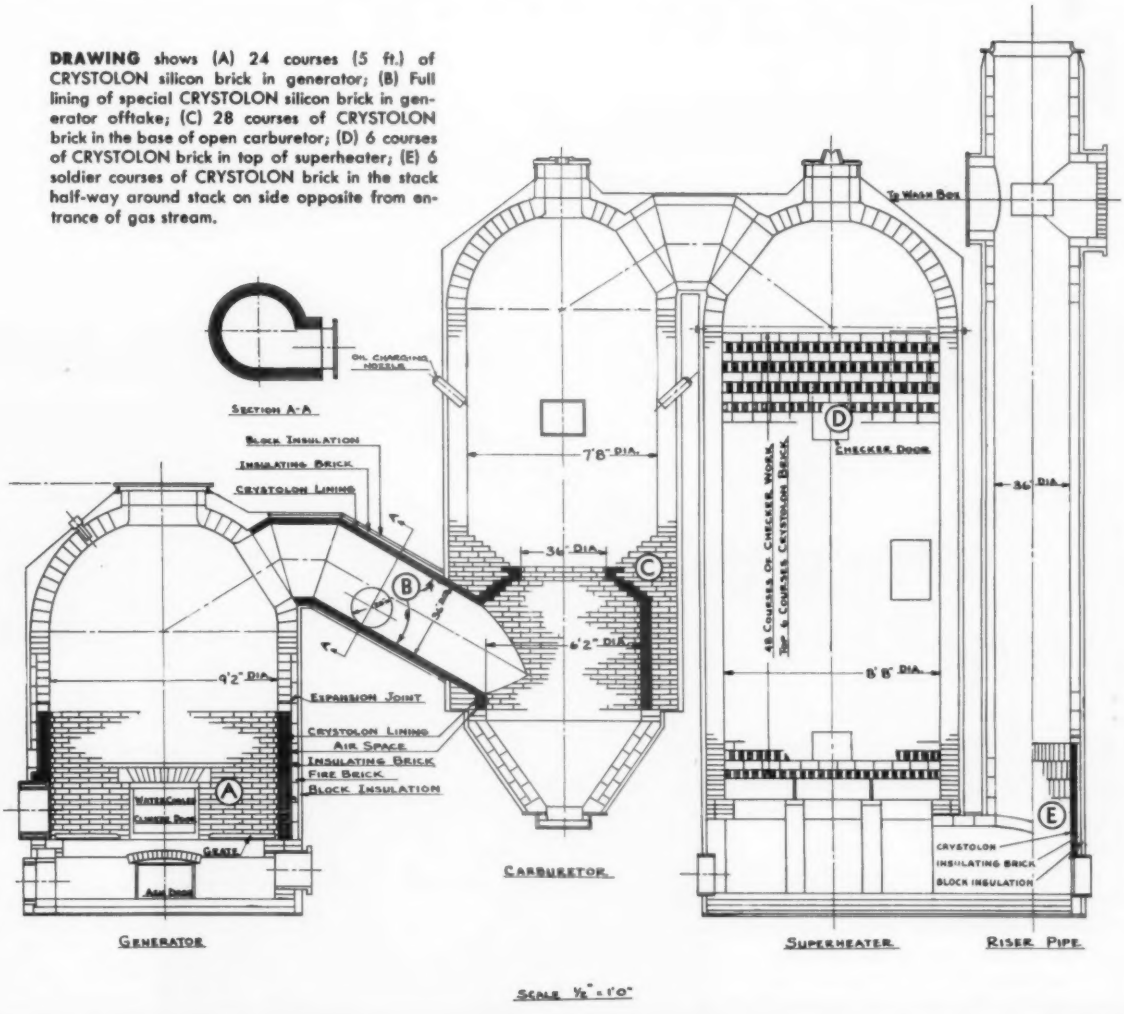
AIR LINE MASK

SPRING HEEL PLUG

Patented

Type #6 for right angle fittings. Type #7 for 45 degree fittings. Equipped with our patented Spring Heel, which forces the plug in past the fitting and keeps it there until you are ready to release it. Plug is withdrawn.

DRAWING shows (A) 24 courses (5 ft.) of CRYSTOLON silicon brick in generator; (B) Full lining of special CRYSTOLON silicon brick in generator offtake; (C) 28 courses of CRYSTOLON brick in the base of open carburetor; (D) 6 courses of CRYSTOLON brick in top of superheater; (E) 6 soldier courses of CRYSTOLON brick in the stack half-way around stack on side opposite from entrance of gas stream.



CRYSTOLON* Brick Lining

helps cut cost of gas generator operation in sets producing either oil gas or water gas

The CRYSTOLON brick installation shown in diagram was specified by a New England utility plant for use in a Semet-Solvay reverse flow set producing water gas. Selected because of its outstanding resistance to slag action, penetration, and abrasion, this time-tested Norton refractory outlasts other refractories three to four times or more in gas-making hours. CRYSTOLON linings have given over 22,000 hours of service.

CRYSTOLON brick are equally effective when used as checkers or linings in Oil Gas Generators. Gas sets — like that illustrated above — have been converted from water to oil gas in many communities now being served by natural gas. The set is used during peak operating periods and to provide a stand-by supply.

You cut cleaning time, reduce down-time, lower over-all costs when you use CRYSTOLON brick for your generator. Depend on this Norton lining to help you get maximum production.

For complete details on Norton refractory linings, send for the illustrated booklet, "Lining and Repairing Water Gas Generators," Form 1408, Norton Company, New Bond St., Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto, Ont.

*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries

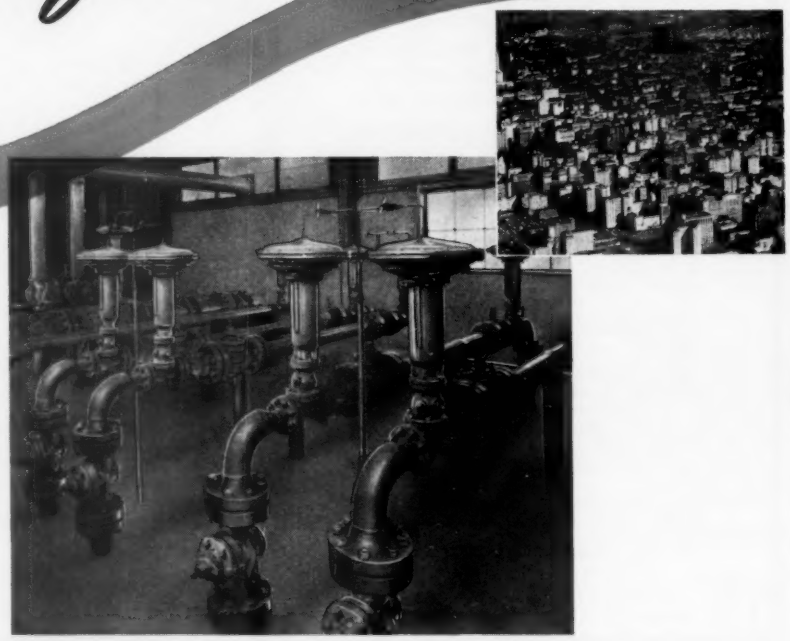
NORTON

Special REFRACTORIES

Making better products to make other products better

NORTON COMPANY, WORCESTER 6, MASSACHUSETTS

SPECIFY RELIANCE TYPE "P" *Streamflow* REGULATORS FOR SUPERIOR PERFORMANCE



Single valve construction eliminates possibility of knocking and insures streamflow of fluids with minimum turbulence.

Expansion of fluids occurs downstream, thus relieving working parts from any scouring action or shock. A removable valve seat tube with long extension throat made of stainless steel, takes the force of expansion and turbulence.

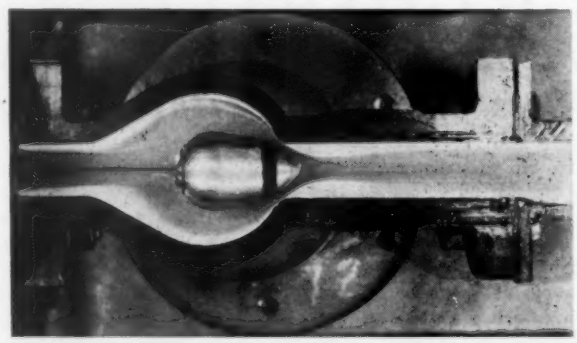
Freezing of valve and other working parts is minimized due to expansion of fluid beyond these members. The velocity of fluid moving away from outlet of regulator minimizes the possibility of ice or frost formation and the force of expansion is gradually dissipated over a large area.

The power for valve operation is transmitted from a conventional type of diaphragm chamber to a cam member which actuates a bell crank carrying the valve. The valve is self-centering with orifice throat and operates on a ball and socket joint which gives perfect alignment.

ALL RELIANCE REGULATORS are made from the best quality materials obtainable and their dependable performance has been proven by the operating results of thousands now in service.

You can rely on
RELIANCE REGULATORS
For complete data, request
Bulletin No. 42-C

A battery of 2 inch large capacity type "P" streamflow *gas pressure reducing regulators, instrument controlled, on a large western distribution system.*



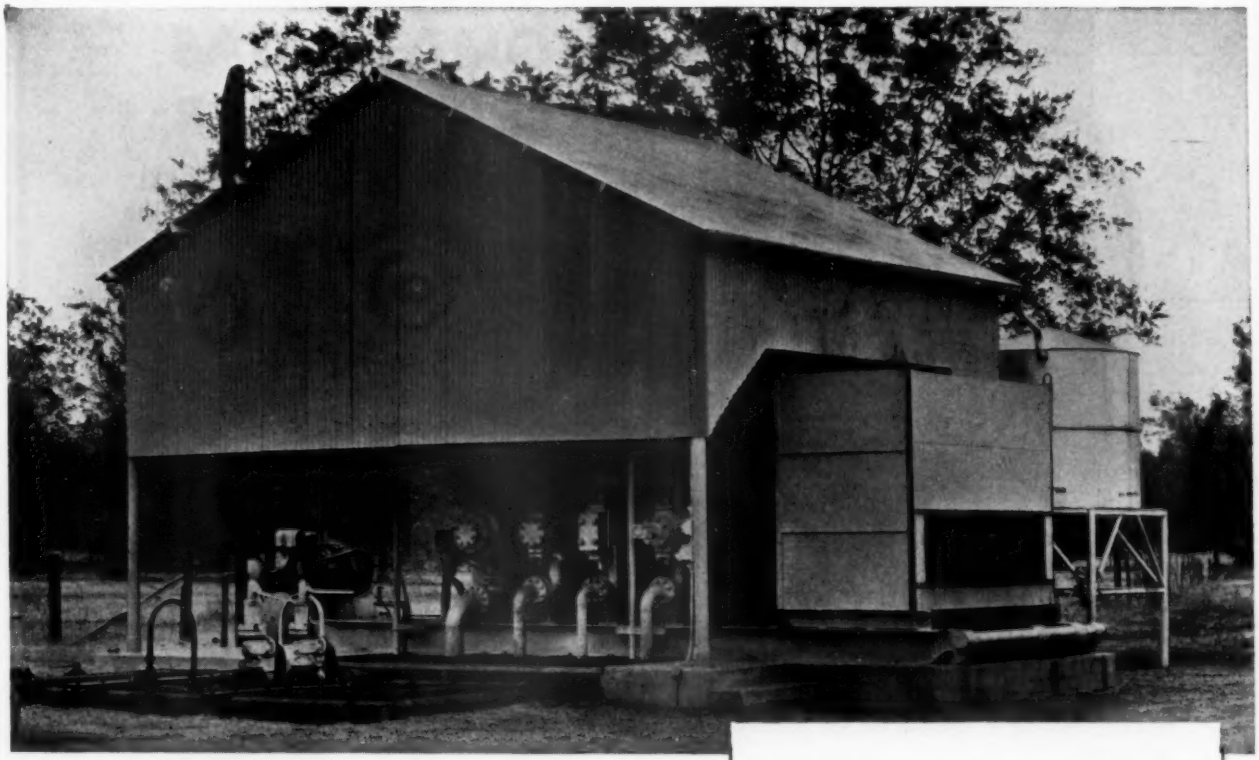
Sectional view of streamflow *characteristics—valve in open position. Note curvature of fluid flow in* streamlined *movement and clear converging of stream discernable at outlet throat.*

RELIANCE REGULATOR DIVISION
1000 MERIDIAN AVENUE, ALHAMBRA, CALIFORNIA

AMERICAN METER COMPANY
MEASUREMENT ENGINEERS

AMERICAN METER COMPANY
INCORPORATED • ESTABLISHED 1836

field gas pressures falling?



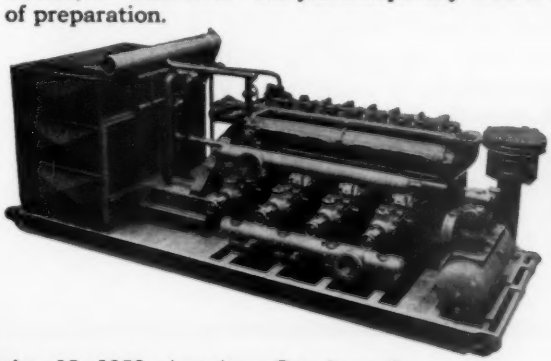
Clark has the answer... "Midget Angles"

Are you confronted with the problem of field gas pressures falling faster than anticipated? Do you have inadequate compressor horsepower in existing field gathering stations to cope with these conditions?

The obvious answer, of course, is to add more horsepower. Where and how to install it with the least possible disruption of existing plant facilities is an additional problem. The most economical location, not only from the standpoint of reduced pipe size and consequently reduced cost, but also with overall horsepower requirements in mind, is at the point of highest suction pressure or at the well. The simplest, most practical field compressor suited to this use is the Clark Midget Angle.

Factory "packaged" into a complete semi-portable compressor station, it is all set to go to work the day it is received. It has the stamina and ruggedness — the Clark quality and dependability backed by over 600 field installations, to "take over" the job completely with a minimum of preparation.

- **Perfect balance virtually eliminates foundation. A simple concrete slab is sufficient.**
- **Needs only a roof in most cases.**
- **Ready to tie in the day it arrives. It's "factory packaged".**
- **Because it's so rugged, very little attention is required. One man can handle a number of units.**
- **Does not interfere with present compressor station facilities.**
- **Easily trucked over lease roads and bridges without disassembly. It's small and compact.**



CLARK® compressors

CLARK BROS. CO. • OLEAN, N. Y.
Division of Dresser Operations, Inc.
OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD
Gas-Engine-Driven • Steam-Engine-Driven
Motor-Driven • Centrifugal • Axial Flow

AUTOMATIC GAS WATER HEATER

The simplicity of the design of the new REX "XL" AUTOMATIC GAS WATER HEATER is alluring. The eye of the artist sees in it the fullest possible expression of his ideal.

It is a water heater that contributes automatically and economically to the comfort of the home by giving an ample supply of hot water at the desired temperature.

It is a water heater that brings beauty, new freedom and greater satisfaction to the home.

Salient REX "XL" Features

OUTSTANDING IN DESIGN. Pleasingly round, slightly ornamental, low contour are features of the new REX "XL" AUTOMATIC WATER HEATER; making it suitable for the kitchen, utility room or recreation basement.

ECONOMICAL IN OPERATION. A thick layer of insulation, covering sides as well as top, keeps the water hot. The REX Burner properly adjusted, is an assurance that every cubic foot of gas is effectively used.

PRACTICAL TO USE. The temperature of the water may be adjusted to suit the convenience of the user.

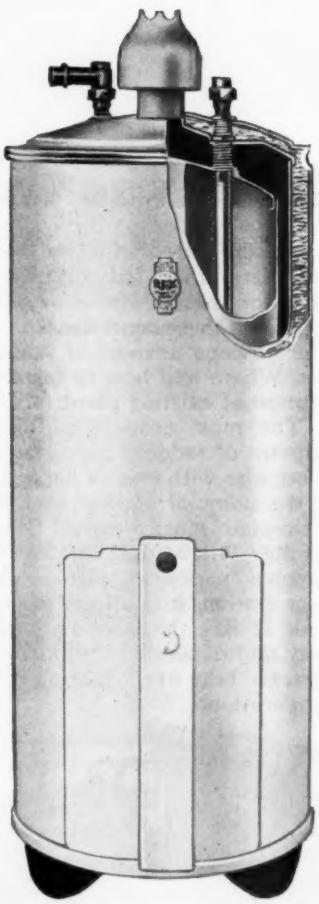
DOUBLE EXTRA-HEAVY STORAGE TANK. Made of copper-bearing steel, galvanized with virgin spelter, and protected for long life with an "Elno" Anodic Rod. The tank is of the floating type—every inch of its surface is subjected to heat.

SAFE TO USE. A 100 per cent Safety Pilot cuts off the gas supply to the main burner and the pilot should the pilot extinguish. A Temperature and Pressure Relief Valve makes the REX "XL" safe to use in any home.

BUILT TO LAST. In every detail of construction, design and choice of materials particular care has been taken to build a water heater that will give the most satisfactory service for years to come at consistently low operating cost.

EASY TO INSTALL. Its compact design makes installation easy.

EASY TO SELL. Available in six sizes: 20, 30, 40, 50, 60, and 75-gallon capacity. There is a size for every home. Moreover, it has all the features the housewife could demand.



Without Exaggeration the REX "XL" AUTOMATIC GAS WATER HEATER may be called the Ultimate in Automatic Hot Water Service.

THE CLEVELAND HEATER CO.

2310 Superior Avenue Cleveland 14, Ohio

CARBIDE AND CARBON CHEMICALS COMPANY

A Division of Union Carbide and Carbon Corporation

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WHERE YOU CAN PROFIT FROM CARBIDE'S SYNTHETIC CHEMICALS

PREVENTING DRY GAS LEAKAGE—CARBOSEAL Anti-Leak saturates bell-and-spigot joint packings of dry gas distribution systems, swells the jute and hemp fibers as much as 44% of their dry volume, and keeps the system gas tight for an extended period of years without re-treatment. By introducing CARBOSEAL Anti-Leak into your mains, you can obtain as high as 100% reduction in leakages eliminate a hazardous condition and vegetation damage, and reduce maintenance costs. Your entire system can be treated conveniently and economically without uncovering every joint and without need of continuous rehydration and oil fogging.

REDUCING DUST PROBLEMS—CARBOSEAL Anti-Leak wets down rust and dirt in the mains of dry gas distribution systems, thus reduces service calls due to pilot outages. The average cost of CARBOSEAL Anti-Leak to treat one mile of 3-inch equivalent main is less than $100. Mains treated 17 years ago have remained gas-tight to date without further treatment.

DEHYDRATING—A dehydration plant utilizing Diethylene Glycol or Triethylene Glycol will prevent formation of natural gas hydrates in transmission lines. This helps maintain transmission line capacity, avoids valve and regulator clogging, eliminates the cost of line heaters or adding anti-freeze agents during cold weather operation, and protects the system against bothersome winter freeze-ups. Both large, centrally-located plants and small, packaged well-head units are widely used.

DESULFURIZING—Monoethanolamine and Diethanolamine plants efficiently scrub corrosive and toxic hydrogen sulfide out of natural or refinery gas. The hydrogen sulfide removed may be a source of saleable sulfur. Carbon dioxide is simultaneously removed from the gas stream in most plants.

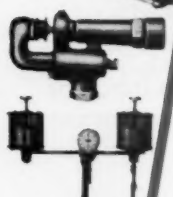
REMOVING GUM AND TAR—CELLOSOLVE solvents are used to flush out old gum and tar deposits in drips or gas holders. UCON fluid 50-HB-55 also has a solvent action on gums formed in manufactured gas equipment, making it useful for reducing gum clogging of pilots and regulators.

BREAKING EMULSIONS—Amine 220 is a de-emulsifier for breaking troublesome tar-water emulsions which often occur in water gas manufacturing plants.

ENGINEERING ASSISTANCE—Write today for engineering data or information on any of these chemical applications or processes.

"CARBOSEAL," "UCON," and "CELLOSOLVE" are registered trade-marks of Union Carbide and Carbon Corporation.

BUY NORWALK CONTROL EQUIPMENT BIG OR LITTLE



Industry's Complete Line

Next time you need gas control equipment or some engineering advice, call on Norwalk. We've been helping gas companies and gas users with their distribution and control problems for 70 years. For your convenience and quick service, competent engineers are located at 11 convenient factory branches and at our South Norwalk plant.

DELIVERIES

Smaller Norwalk products can be picked up at our 11 branches. Larger regulators and check valves . . . even in the 36" sizes . . . can be manufactured quickly to order. In cases where speed is important, your order should list all pertinent information such as type of gas, inlet pressure, back pressure and type of drilling desired on flanged sizes. Before ordering be sure to go over carefully the catalog sheet on the Norwalk product involved.

SPECIAL DESIGNS

Norwalk engineers will gladly design special regulators or valves to meet any extraordinary requirement that has to do with control or distribution of gas.

COMPLETE ENGINEERING CO-OPERATION

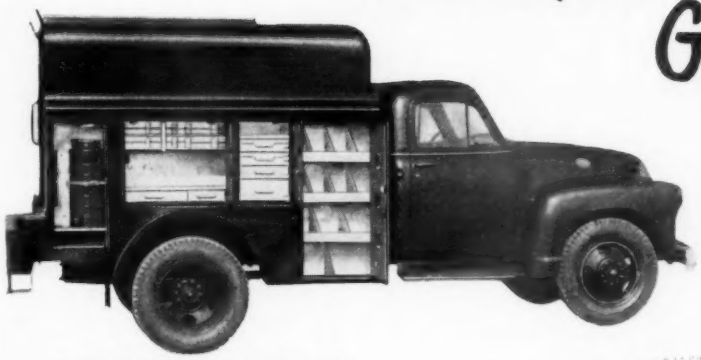
NORWALK VALVE COMPANY

SOUTH NORWALK, CONN.

Norwalk & Connelly Valves, Regulators, Governors, Controllers, Filters and Gauges

MANUFACTURERS OF GAS PRESSURE REGULATORS SINCE 1878

The dependable name for Gas Utility Bodies



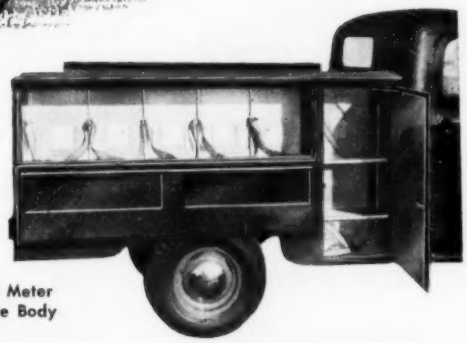
CL-112 Light Gas Construction and Maintenance Body

There are Holan body models for every type of gas construction, maintenance and service work. They have the latest engineering features that help your crews operate more efficiently.

The wide selection of Holan standard body models eliminates, in most cases, the necessity of ordering expensive special body models.

HOLAN

1051 Gas Construction Body



1090 Meter Service Body

1563 Compressor Body

HOLAN UTILITY EQUIPMENT FOR THE GAS INDUSTRY

Gas Construction Bodies (with or without crew compartments)
Air Compressor Bodies
Crew Carrier Bodies
General Service Bodies
Gas Meter Installation Bodies
Appliance Installation Bodies
Winches and Power Take-offs

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FIELD ENGINEERS IN PRINCIPAL CITIES

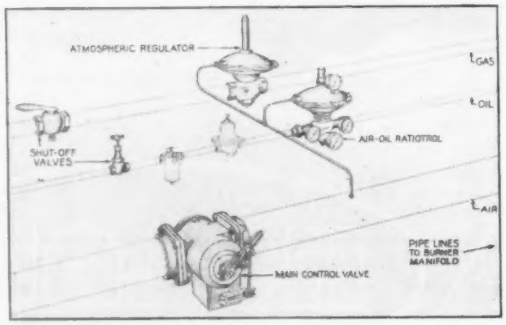
MANUFACTURERS OF INDUSTRIAL FUEL BURNING EQUIPMENT FOR GAS OR OIL

ADJUSTABLE PORT VALVES, BUTTERFLY VALVES AND SENSITROL OIL VALVES, VARIOUS TYPES OF PREMIX, NOZZLE MIX AND LUMINOUS FLAME GAS BURNERS. VARIOUS TYPES OF LIGHT OR HEAVY FUEL OIL BURNERS. BURNER MOUNTINGS, REGISTERS, BURNER TILES, ETC. FUEL-AIR MIXTURE CONTROLS. ATMOSPHERIC GAS REGULATORS AND AIR-OIL RATIOTROLS. SAFETY SHUTOFF VALVES FOR PROTECTION. FOR PROCESSING AND BOILER USAGE.

GAS OR OIL FIRED IN SAME EQUIPMENT

One valve control automatically maintains the fuel-air ratio of any number of burners, fired with either gas or oil.

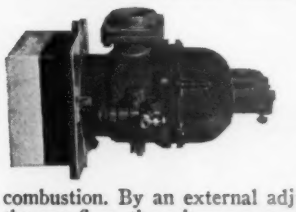
In the North American pressure system of proportioning, the oil or gas pressure is directly proportional to the air pressure on the outlet side of the main control valve. Thus,



air or fuel pressure variation, or number of burners in operation have no effect on the fuel-air ratio, thereby maintaining maximum operating efficiencies.

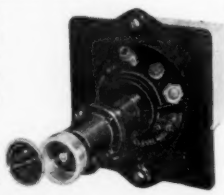
Furthermore, the firing rate or the mixture of any burner can be changed without affecting the fuel-air ratio of any other burner operated from the same control.

LUMINOUS FLAME GAS BURNERS



North American Luminous Flame Burners develop flames of high luminosity. They give good results in furnaces of various sizes and design and are recommended for all heating processes that benefit from the application of luminous flame combustion. By an external adjustment changing the direction of the gas flow, these burners can also be operated with shorter and less luminous flames. Capacities range from 125 to 8,000 cu. ft. per hour of natural gas. Oil inserts are available for Dual-Fuel firing.

CERTIFIED COMBUSTION GAS BURNERS



This newest and most all-embracing gas burner has factory preset air-gas ratio for positive initial lighting. Subsequent readjustment for ratio changes or gas type changes are readily made from tabled data on the cover plate.

Zero gas provides control simplicity and ratio fidelity. Nozzle mixing eliminates flashbacks. Extreme volumetric turndowns 17 to 1 require only 24 oz. air, yet mixture fidelity within 1% CO_2 is maintained.

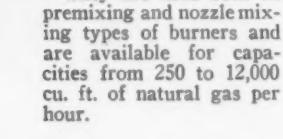
The assembly is complete with burner, mounting, mixer, tile, observation lens and apertures for flame rod and for pilot.

ATMOSPHERIC REGULATORS

The North American Atmospheric Regulators are designed to give definite ratios between gas and combustion air when the flow of both fluids is simultaneously affected by the control of one fluid only.

They are used both on premixing and nozzle mixing types of burners and are available for capacities from 250 to 12,000 cu. ft. of natural gas per hour.

HIGH PRESSURE INSPIRATORS



High Pressure Inspirators utilize the energy in the gas stream to inspirate all or part of the air required for proper combustion. To accomplish this, certain relationships between orifice area, throat area, and burner area must be maintained. North American High Pressure Inspirators are designed and machined to conform with the above principle. Gas orifice and inspirator throat are in perfect alignment while the air shutter closes tightly and can be locked at any desired setting.

TURBO BLOWERS

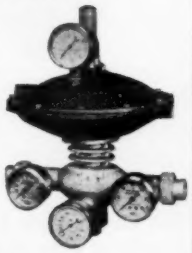
North American Turbo Blowers are driven either directly by 3,600 rpm ball bearing motors or by V-belt drives when slower speed motors or other than 60 cycle currents are used.

They deliver a constant outlet pressure, which is especially desirable for combustion work.

North American Turbo Blowers are made in many sizes ranging from 60 cfm at 8 oz. to 4,000 cfm at 32 oz.

The illustrated Turbo Blower has a rating of 850 cfm at 8 oz. pressure.

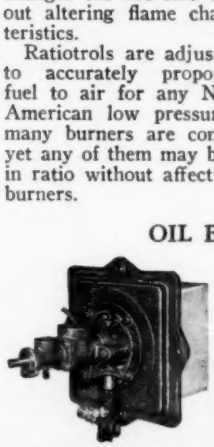
AIR-OIL RATIOTROLS



Burner *air pressure* determines burner *oil pressure* in oil burning systems using Air-Oil Ratiotrols. A change in the manual or motorized air control valve changes the fire size without altering flame characteristics.

Ratiotrols are adjustable to accurately proportion fuel to air for any North American low pressure air-oil burner. One or many burners are controlled by each Ratiotrol, yet any of them may be cut in or out or changed in ratio without affecting the ratio of companion burners.

OIL BURNERS



North American Oil burners are available for high or low pressure air or steam atomization. The illustrated burner uses constant atomizing pressure for uniformly high combustion efficiency at all stages of turndown. Large and direct air and oil passages require little cleaning. Mountings, registers and tiles form integral parts of the assembled burner. Dual-Fuel burning features are available.

How Lincoln Arc Welding Cuts Construction and Maintenance Costs

MANY gas companies are extending the cost-saving benefits of arc welding to the construction and maintenance of gas transmission lines and all types of processing equipment with Lincoln arc welders. Low in cost and unusually simple to operate, Lincoln welders are preferred everywhere for their dependable performance and versatility to handle a wide variety of repair and construction work on all types of metals.

Lincoln DC arc welders are available in 200, 300, 400, 600, and 900 amp capacity. Rubber-tired undercarriages can be provided for towing. All engines and generators are completely enclosed in canopies to afford maximum protection from weather.

Lincoln AC welders are furnished in 200, 300, and 500 amp sizes. Faster, simpler AC welding is assured with Lincoln's famous "Arc-Booster" that starts the arc automatically each time the electrode touches the work.

Lincoln Electric provides complete welding service on any arc welding problem. World-famous Lincoln electrodes are available to satisfy practically every welding need, producing highest quality welds at lowest cost. Factory-trained welding specialists are stationed in every principal city the world over to recommend proper equipment and assist with welding procedures. Consult your telephone directory for your nearest Lincoln office or Weldealer.

Fig. 1—*Arc welding fifteen hundred foot 8" gas line extension line for the East Ohio Gas Company. Pipe ends are bevelled and butt welded with three passes of "Fleetweld 5" electrode. Photo courtesy Hattendorff-Bliss Co., Euclid, Ohio.*

Fig. 2—"Fleetwelder 200 AC". *Lincoln, low priced, 200 amp AC arc welder with "Arc-Booster". Operates on single phase current. Mounted on wheels for portability.*

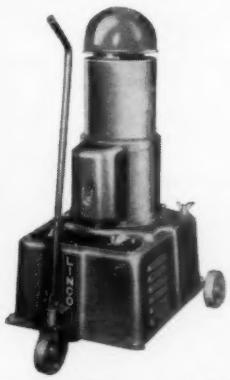


Fig. 3—200 amp electric motor driven Lincoln "Shield-Arc Jr." *DC arc welder, portable model. Available for AC power supply, 2 phase or 3 phase.*

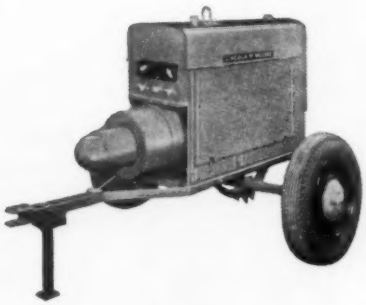


Fig. 4—200 amp engine driven "Shield-Arc" DC *Lincoln portable model with two-wheel undercarriage shown. Has patented idling device to save fuel, oil and engine wear.*

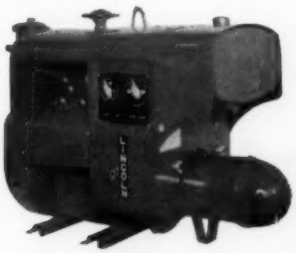


Fig. 5—200 amp Lincoln "Shield-Arc Jr." DC, *air-cooled engine driven arc welder. Compact in construction for simple transportation on light pick-up truck or on 2-wheel undercarriage.*

THE LINCOLN ELECTRIC COMPANY

The World's Largest Manufacturer of Arc Welding Equipment

Cleveland 17, Ohio

Branch Offices and Field Service Shops in All Principal Cities

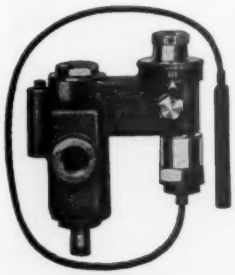
PARTLOW Temperature Controls

Ten Ranges—30° to +120° F; 0° to 150°; 0° to 250°; 50° to 350°; 100° to 450°; 0° to 500°; 100° to 650°; 100° to 800°; 100° to 1000°; Special 100° to 1200° Fahrenheit.
Centigrade Ranges on Request

Partlow Temperature Controls, Recorders, Dial Thermometers, Limit Switches, Safety Gas Valves and Timers are made in a variety of Types and Models, some of which are shown below:

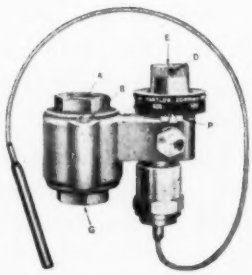
Calibrated & Uncalibrated

Non-Indicating Throttling Type Temperature Controls for industrial process heating installations using high or low pressure gas



Series 70

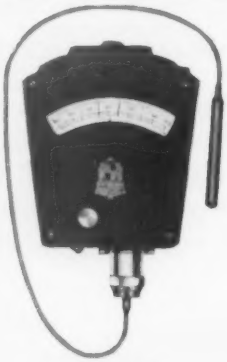
Series 20



Series 40

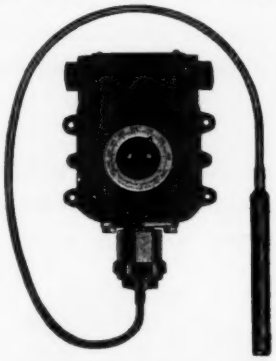
Electrically Operated Temperature Controls for industrial processes utilizing gas, oil, steam or electric heating

Model RS
Recording



Model BSS
Two Point—Indicating

Model MS
Single Point—Indicating



Model ZS
Single Point—Non-Indicating

Time Delay Relays

Model 308

Saf-T-Flame Relay Cabinets

Push Button Ignition Type
Models SF-711 and SF-712

Automatic Ignition Type
Models SF-721 and SF-722

Thermometers

Model TA

Please write for: "The Engineers Guide to Industrial Temperature Control" (Bulletin 101); and the handy chart "Selecting the Proper Industrial Temperature Control"

THE PARTLOW CORPORATION

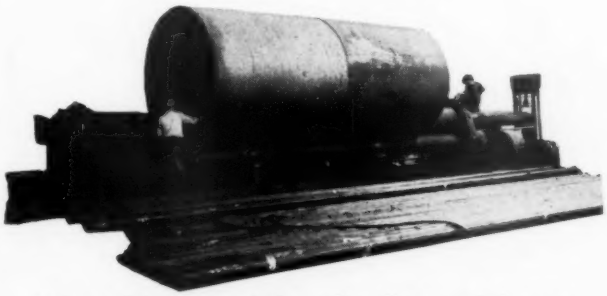
New Hartford (*Suburb of Utica*) **N. Y.**

WE HAVE SUBSCRIBED FULLY TO THE "CODE OF ETHICS" ADOPTED BY THE INDUSTRIAL DIVISION OF G.A.M.A.

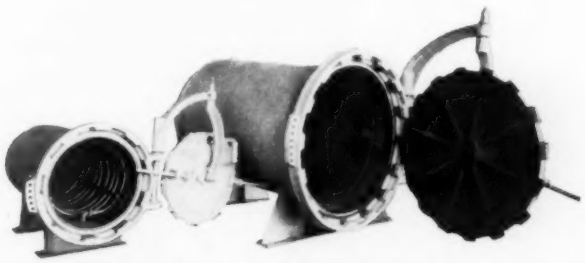
POSEY PRODUCTION FACILITIES
Save You Money on POSEY PRODUCTS

Steel plate construction is seldom "standard." Nearly always, it must be "tailored" for the individual user. That's why Posey believes that specifications and dimensions of past installations mean less to plant engineers than the answer to the question: "Have they the production capacity and the equipment to do my job economically and to deliver it on time?"

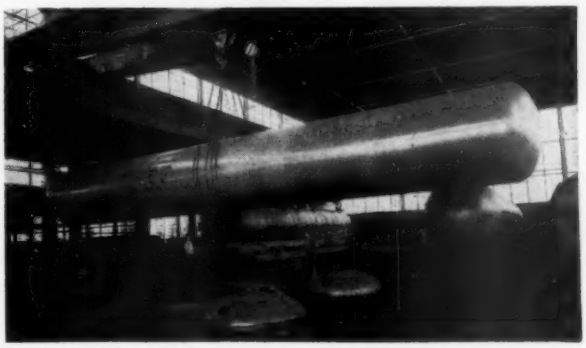
Located in Lancaster, Pa.—a railroad and highway center—the modern plants of the Posey Iron Works cover an area of 16½ acres under roof. Feature of recent expansion has been the addition of modern equipment. Some of this equipment is pictured below. Detailed information about Posey plant and equipment is available in an illustrated 12-page bulletin—sent free on request.



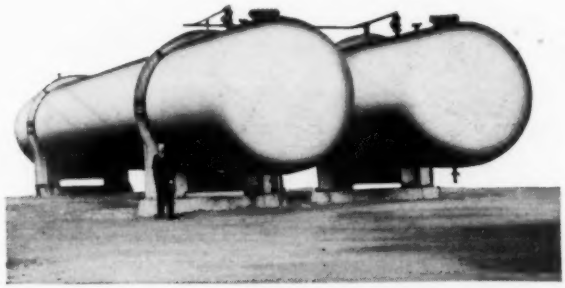
32-foot roll bending steel plate. This roll is one of the new equipment units in the North Plant which covers 13½ acres.



Pressure vessels are a specialty at the Posey Iron Works.

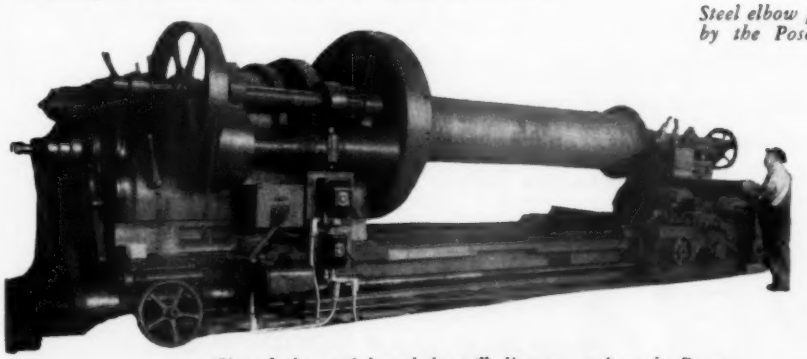


This 50-ton crane (27-foot headroom) allows quick, easy handling of sizeable units like the horizontal tank shown.



The Posey Iron Works fabricates storage tanks up to all capacities. All standard codes are met with adequate allowance for safety factors.

Steel elbow piping fabricated by the Posey Iron Works.



Giant lathe—16' length by 94" diameter—gives the Posey Iron Works an edge on large jobs requiring lathework.

POSEY IRON WORKS, INC.

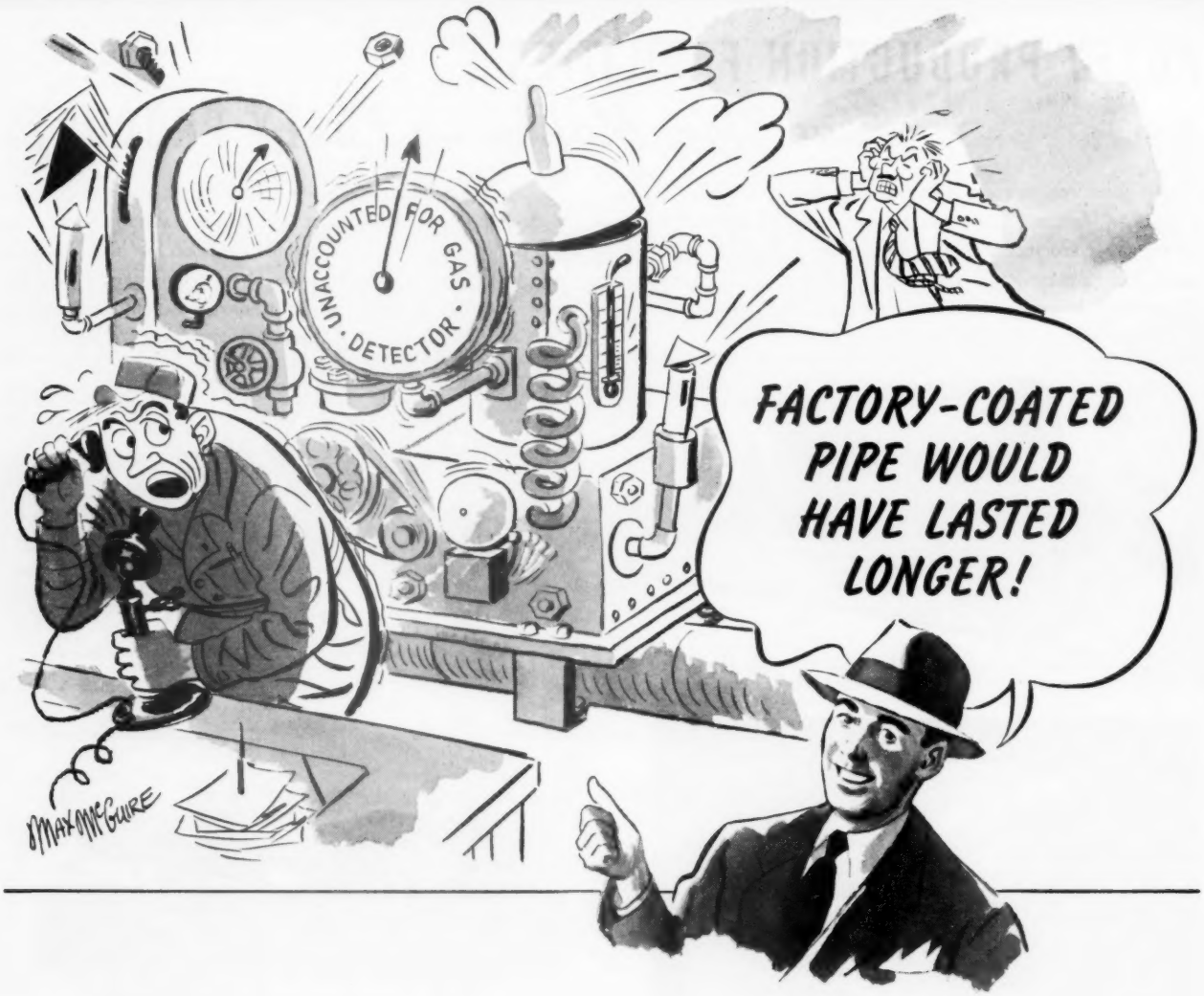
Steel Plate Division

LANCASTER, PA.

New York Office: Graybar Building

ESTABLISHED SINCE 1910

DIVISIONS
Brick Machinery
Foundry
Industrial Heating
Iroquois
Shipbuilding
Steel Plate



WHY?

Hill, Hubbell factory-coated pipe lasts longer because all conditions can be precisely controlled at the factory and they can't in the field. With Roto-Grit Blast, we carefully clean every joint of pipe before coating. All coatings and wrappings are precision applied at uniform temperature. Every joint is inspected with electronic holiday detectors before leaving the factory.

Hill, Hubbell and Company

Division of GENERAL PAINT CORPORATION

Headquarters: 3091 Mayfield Road, Cleveland 18, Ohio

Leaders in Pipe Protection for a Quarter Century

PLANTS: Lorain, Ohio ☆ Youngstown Area—at Girard, Ohio
Chicago Area—at Hammond (Gibson), Indiana.
Railroad in transit privileges.

EFFICIENT MOBILE AIR POWER for UTILITIES

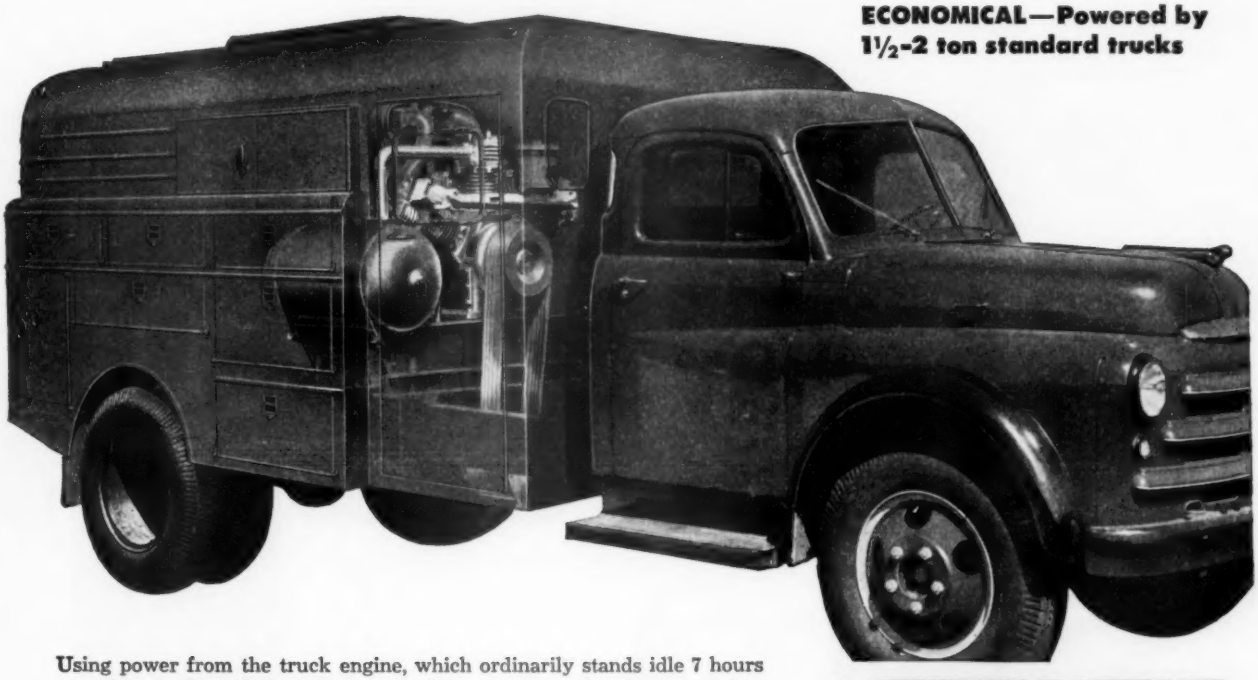
Jaeger Travel-air compressor with Cemco power take-off

125 CFM OF AIR
runs 2 heavy breakers

NO VIBRATION-2 stage,
W-type compressor unit

SIMPLE AUTOMATIC
CONTROL of Engine Speed

ECONOMICAL—Powered by
1½-2 ton standard trucks

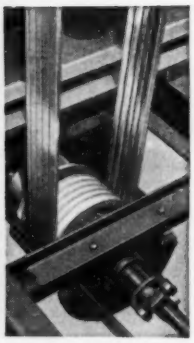


Using power from the truck engine, which ordinarily stands idle 7 hours out of 8, the Travel-air delivers 125 cfm at 100 psi — the air you need to run 2 heavy pavement breakers at full pressure — with engine operating at an easy 1750 rpm (24 mph speedometer). The automatic control that regulates engine speed to air requirements is simple, positive, employs no complicated linkage. Average engine life, on compressor service, is equivalent to 200,000 miles.

Cemco take-off has only 4 moving parts — no gears. Easy to mount on 1½ and 2 ton Chevrolet, Ford, Dodge, GMC and International trucks of long wheelbase model. For full information, and prices $950 to $1000 lower than trailer-type compressors requiring separate engine, see your Jaeger distributor or send for Catalog TC-1.

Every major utility, from New York to California, that has installed Jaeger Travel-air Compressors on their service trucks has ordered additional units for their fleets.

Speed Control

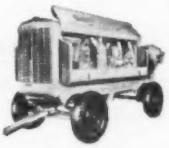


Power Take-Off

"Air Plus" Trailer Compressors deliver up to 25% more air to match today's tools.

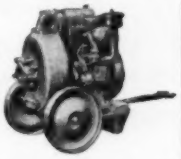
At full pressure, air tools do 30% to 40% more work than at 70 lbs. pressure. Jaeger's "new standard" ratings insure full pressure operation.

Model 75 operates a heavy breaker, Model 125 two heavy breakers, Model 185 three heavy breakers at full pressure. 250, 365 and 600 ft. models offer comparable advantages. Catalog JC-1.



"Sure Prime" Pumps: Capacities to 240,000 gph; pressures up to 275 lbs.

Heavy duty dependability and long service in portable pumps for all types of drainage work, by-pass pumping, jetting and emergency water supply.



Aluminum pumps: 1½" Bantam (60 lbs.) 5100 gph; 2" (105 lbs.) 9000 gph. 2" to 10" semi-steel dewatering pumps; 3" to 6" high pressure pumps. Write us for Catalog P-10.

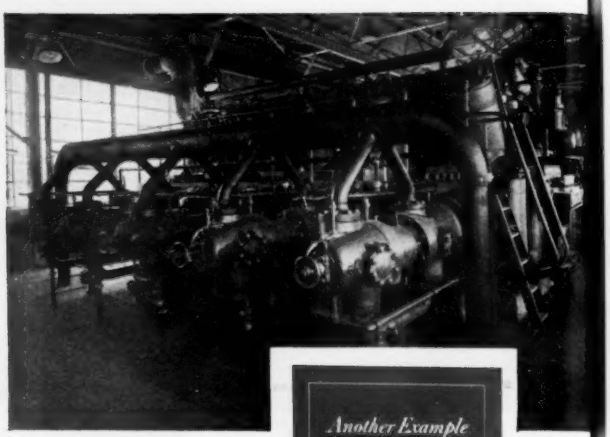
Sold, rented, serviced by leading distributors in 153 cities of U.S. and Canada

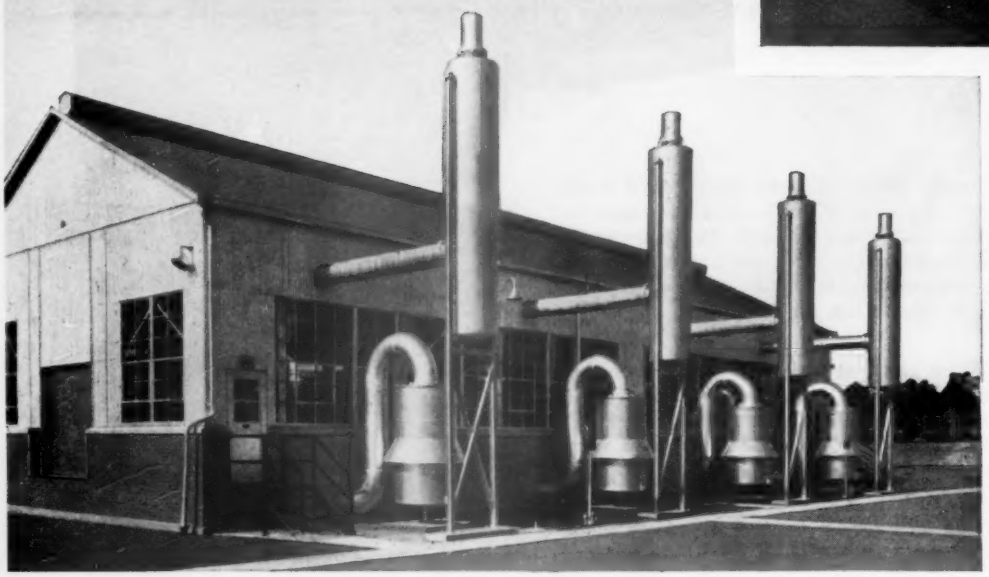
THE JAEGER MACHINE COMPANY 668 Dublin Avenue Columbus 16, Ohio

CONCRETE MIXERS • HOIST TOWERS • AGGREGATE SPREADERS • SCREW SPREADERS and FINISHERS for CONCRETE PAVEMENTS

In Oklahoma Natural's largest gas-storage project . .

. . a lot of compressing in small space with compact GMV's





Another Example of Efficient Power at Lower Cost

● Look at the size of the building . . and the neat compactness of this 4400-hp GMV compressor set-up. Here, at Depew, Oklahoma Natural Gas Company is equipped to handle approximately 160,000,000 feet per day with a suction pressure of 500# and a minimum injection pressure of 800#—a lot of compressor work with a minimum of installation and operating overhead.

Note also that these Cooper-Bessemer V-angles are driving 5 compressor cylinders per unit . . . in other words, a compressor cylinder for *every* crankthrow.

Add up the advantages you stand to gain with Cooper-Bessemer V-angles—proved month-in-month-out availability, unmatched compactness, and overall operating efficiency that has yet to be equalled! Get *all* the facts. You'll see why Cooper-Bessemer V-angles are preferred units in *every* type of heavy-duty compressor service.

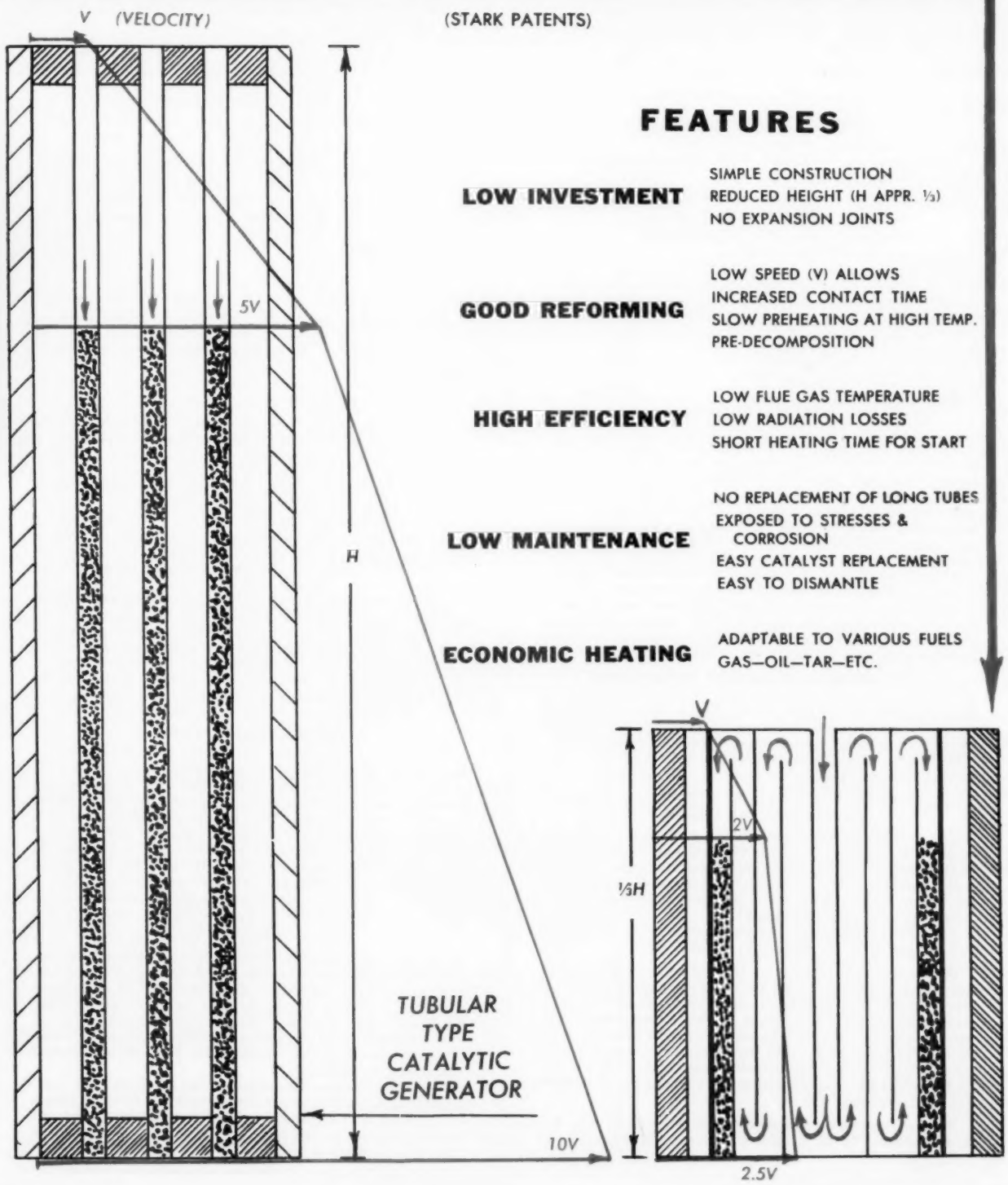
The Cooper-Bessemer Corporation

MOUNT VERNON, OHIO — GROVE CITY, PENNA.

New York City Washington, D. C. Bradford, Pa. Parkersburg, W. Va.
San Francisco Houston, Dallas, Greggton, Pampa and Odessa, Texas
Seattle, Wash. Shreveport, La. St. Louis, Mo. Los Angeles, Calif.
Caracas, Venezuela Gloucester, Mass. Tulsa, Okla. New Orleans, La.

CONCENTRIC CATALYTIC GENERATOR

(STARK PATENTS)



FEATURES

LOW INVESTMENT
SIMPLE CONSTRUCTION
REDUCED HEIGHT (H APPR. ⅕)
NO EXPANSION JOINTS

GOOD REFORMING
LOW SPEED (V) ALLOWS INCREASED CONTACT TIME
SLOW PREHEATING AT HIGH TEMP.
PRE-DECOMPOSITION

HIGH EFFICIENCY
LOW FLUE GAS TEMPERATURE
LOW RADIATION LOSSES
SHORT HEATING TIME FOR START

LOW MAINTENANCE
NO REPLACEMENT OF LONG TUBES EXPOSED TO STRESSES & CORROSION
EASY CATALYST REPLACEMENT
EASY TO DISMANTLE

ECONOMIC HEATING
ADAPTABLE TO VARIOUS FUELS
GAS—OIL—TAR—ETC.

NORTH AMERICAN UTILITY & CONSTRUCTION CORP.

CHRYSLER BUILDING **NEW YORK 17, N. Y.**

ANDALE

Heat Exchangers . . . Strainers . . . Valves

HEAT EXCHANGERS

Gas Coolers, Aftercoolers,
Air Coolers, Aftercoolers,
Oil Coolers, Lubricant circuit,
Oil Coolers, Quenching oil,
Jacket Water Coolers,
Condensers, Ammonia,
Condensers, Process Vapor,
Condensers, Carbon Dioxide,
(Heaters, Unfired).
Fuel Oil Heaters,
Feed Water Preheaters,
Tar Heaters,
Waste Heat Recovery,
Stills,
Reboilers

Tube Bundle type only. Standard Designs. Special Designs. Standard and Special Materials.

Tubes seamless, cold drawn. Tube ends expanded metal-to-metal in both tube sheets.

Andale STANDARD Designs.

———With tube-bundles REMOVABLE:

One end or both ends floating.

With straight tubes. Tube bundles with same baffling, or with different baffling, are interchangeable in shells of the same design and size. Repairable. Both sides of bundle are cleanable, inspectable. Single pass and multi-pass.

Materials: Suited to the conditions in which the unit is to be used.

Tube lengths: 6¼″ to 192″.
Tubes: 1/4″ to 2½″ o.d.
Shells: 1″ to 72″ i.d.
For Pressures: Vaccuum to 900 lb. sq. in.
For Temperatures: 0°F. to 600° F.

This group of designs includes: Andale Type 202; with heads and tube bundle removable without need of disturbing the pipe connections for the tube stream; which connections are on the outer wall of the shell, and are permanent. Also Designs Type 202 Class IV; with the shell stream in a bored steel shell; with the tube stream touching only non-ferrous metal; with tube stream pipe connections permanent on ring at wall of shell (not on heads).

The various Series of Standard designs include units to serve in all usual (and many unusual) combinations of conditions and requirements. Designs to meet various problems of destructive conditions, water quality, corrosion, abrasion, etc.; and to meet limitations on water quantity, pressure loss, space, weight, etc.

———With tube-bundles NON-REMOVABLE:

With both tube sheets joined permanently to shell; no stuffing box at either tube sheet. Vapor tight or gas tight on shell stream, and tube stream. Steam or other vapor is at outer side of tubes. Some designs with bowed tubes; "Tar heater" types. Other designs with straight tubes. with expansion joint in shell wall.

Andale SPECIAL Designs.

For special results, gases, liquids, situations, operating conditions, controls, etc. Including units of larger size than in standard series. With all parts special, or incorporating some standard parts. With special designs of heads, shell, joint plan, connections, reflux, offtakes, separator, etc.

Special materials, as required.
Pressures: Vacuum to 5000 lb. sq. in.
Temperatures: Minus 100° F. to 1000° F.

We design and make tube bundle type exchangers to duty and material specifications of any department of Government; or to specifications of private industrial companies; to ASME boiler code or any State code; with manufacturer's data reports supplied; with inspection by authorized inspectors of the department or company concerned, by National Board boiler inspectors, or by insurance inspectors. We do not make exchangers to designs not made by us.

We do not issue a catalog of exchangers. Each offer is a design selected by us to meet best the user's requirements and conditions.

STRAINERS. For:

——Oil:
Lubricant Circuit
Fuel; before burner
Cargo
Pipe Line
Storage
Refinery
Aviation Gasoline
—Suction
—Steam
—Process Liquids
—Product Liquids, Paints, etc.
—Recovery of Wanted Solids

——Water:
Sea
Tidal
Harbor
Freshet
Trashy
Well
Corrosive
Contaminated, (Sewage etc.)
Plant Intake
Plant Service lines
Ship Service lines
Municipal Services

——Protection of:
Close Bearings: in Machines, Engines, Generators, etc.
Sensitive Instruments
Pumps
Heat Exchangers
Filter beds
Tanks
Reservoirs
Sprinkler Systems
—Grease Extracting*
—Feed Water Filter*
*(With wrapped Baskets).

With straining openings from 0.0055″ (0.0029″ in some cases); to 3/8″ or larger. Pressures: from suction to 900 psi. Temperatures to 1200 deg. F. Materials suited to the conditions.

BASKET Type Strainers

Baskets removable. Interchangeable. Bodies: cast iron, bronze, cast steel. Tested to 50% over stated rating.

———Single compartment. Simplex. Macomb bodies and other designs. No valve.

———Two-compartment. Duplex. Switchable; with valve integral. Valves disc type or plug type.

——With DISC Type switching valves (two), with globe seats. Rising spindles, outside screw and yoke. One valve controls outlets of the two compartments; other valve controls their inlets. With or without Chain Interlock on the two valves.

——With PLUG Type switching valve (single plug). With Jack in yoke to lift and seat plug. Any turning movement of plug controls simultaneously the inlets and outlets of both compartments. Also made for remote control.

———BASKETS. Styles supplied in strainer bodies: Bucket type. Side-inlet type. Perforated. Mesh. Single wall. Double-wall separable. Designs to be wrapped.

WHEEL Type Strainers

For Water. (Fresh or Salt. With or without Sewage Contamination). Rotary. Continuous flow. Backwash pressure and volume are independent of main stream. Wash boxes are at *both* sides of grid wheel. Backwash flow can be adjusted to quantity of dirt to be washed from grid. Rotating element is completely of stainless steel. Strains through triangular openings in revolving grid. Openings have inscribed-circle-diameters 0.031″ to 0.125″. Strainer sizes for 600 to 25,000 gpm net strained stream.

VALVES

———Duplex Threeway (6 connections); for pressure line. Single plug. Jack in yoke lifts and seats plug. Connections are: main inlet; main outlet; outlet to circuit A, inlet from circuit A; outlet to circuit B, inlet from circuit B. Also made for remote control.

———Threeway (3 connections). Disc type; globe seats. Outside screw and yoke. Angle stem. Position of stem end indicates flow direction.

———For Constant Pressure on Varying Flow. To keep pressure constant* in pipes from which the flows at points of use may vary sharply or be closed completely; (*constant within limit set by the input). Automatic. By sensitive continuous release of surplus.

For promptness, thoroughness, accuracy of service; we request:—In first communication, order or inquiry, relating to any item of equipment, please describe, as completely as possible, the situation in which it is to be used.

ANDALE Company

1768 Cherry Street, Philadelphia-3, Pa. ———————Telephones: Philadelphia-LO-7-6830

STOCKS AND DIES — OSTER — THREADING MACHINES

BUILDERS OF PROFIT-MAKING THREADING TOOLS AND MACHINES SINCE 1893

The Oster Manufacturing Company, 2068 East 61st St., Cleveland 3, Ohio, U. S. A.

NO. 422 POWER VISE STAND
A portable power drive for hand pipe tools.

This low cost machine converts hand pipe tools to power . . . permits any mechanic to thread, cut-off and ream pipe from 3 to 5 times faster than he can do it by hand . . . and with practically no effort.

Standard range is ⅛" to 2" pipe. Equipped with a special, universal drive shaft, the machine has ample power to drive geared receding die-stocks of 2-½" to 8" capacity.

The Oster No. 422 POWER VISE STAND is strongly built yet light in weight and easily portable. *This machine can save money for you!*

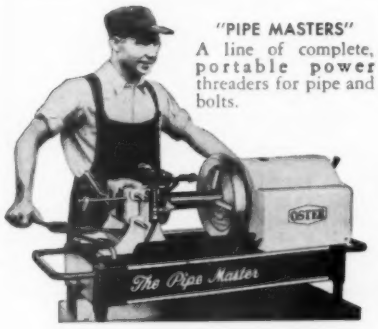
NO. 662 POWER PIPE CUTTER

Capacity: ¼" to 2" Pipe

This compact, portable machine is designed for cutting off small or large quantities of pipe at production speeds that quickly pay for its low cost.

Operated by a universal, variable speed, geared head motor for light socket operation. Motor, idler shaft and cutter shaft are mounted as a unit on a plate hinged to the base casting.

As the hand wheel is turned, the cutter wheel is moved up or down as required. Effort of operator is reduced to a minimum with this machine. *It's a real time-saver!*



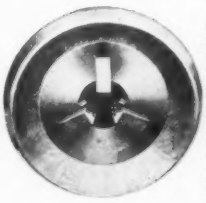
"PIPE MASTERS"
A line of complete, portable power threaders for pipe and bolts.

NO. 502 STANDARD "PIPE MASTER"

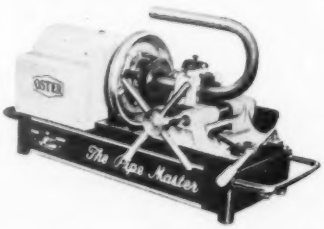
The lowest priced, high quality, complete power pipe machine on the market.

Standard range ¼" to 2" pipe; Extra range ⅛" p.pe. Range with drive shaft 2½" to 8" pipe. Bolt range ¼" to 1½".

Among its many outstanding features is the exclusive Oster "AUTO-GRIP" front chuck, illustrated below.

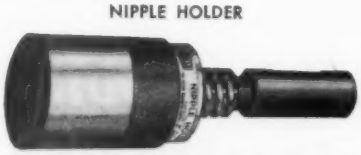


View shows ease of chucking and unchucking pipe with the "AUTO-GRIP" front chuck. Eliminates chuck bar and pipe wrench. Standard equipment on Oster No. 502 and 502D "Pipe Masters" and No. 582 "Tom Thumb" machines.



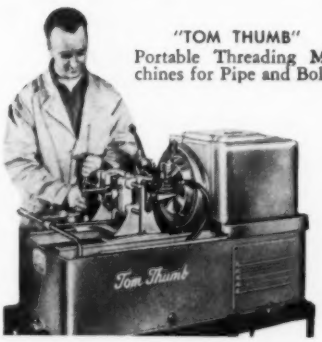
No. 502R "Pipe Master" (Standard Model). Equipped with REVOLVING die-head and open type vise for threading BENT as well as straight pipe. Same range as the No. 502 "Pipe Master" illustrated above.

NIPPLE HOLDER



No. 2 NH Nipple Holder can be used with any make or model of power pipe machine or quick-opening die-stock. This tool makes it easy to thread short and close nipples. "Make your own and save money!"

Range ¼" to 2". Tool is complete with all steel body and 7 adapters. (Body takes 2" size.)

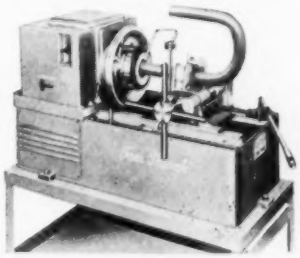


"TOM THUMB"
Portable Threading Machines for Pipe and Bolts.

Oster "TOM THUMB" machines are equipped with BALL BEARING mounted spindle and WORM DRIVE. Features of these machines are comparable to the larger Oster floor type machines.

No. 582 "TOM THUMB" (illustrated above) has Stationary, Quick-Acting Die-Head and "AUTO-GRIP" chuck.

Standard range ¼" to 2" pipe; Extra range ⅛" pipe; Range with drive shaft 2½" to 8" pipe. Bolt range ¼" to 1½".



No. 582R "TOM THUMB" is equipped with REVOLVING Die-Head and Opentype vise for threading BENT as well as straight pipe. All basic features are same as No. 582 machine. Range of No. 582R is same as No. 582.

OSTER "BESTOIL"
A High Grade Cutting Oil at Moderate Price.

High sulphur content in permanent suspension. Absorbs and throws-off heat quickly. Protects life of dies and cutting tools. Flows freely in cold weather. Clean and sterile. Sold in 1 gal. cans and 5, 30 and 55 gal. drums.

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Mechanical Generators and Chargers

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UNITED SERVICES PROVIDE

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United has over 60 years' experience in gas industry construction.

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United has pioneered major developments in city gas and synthesis gas production, catalytically and thermally.

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United has large, well-organized forces for natural and manufactured gas construction work.

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The U.G.I. Mechanical Generator is established as a rugged, reliable and efficient self-clinkering generator, that makes an important contribution to betterment of gas plant labor conditions. Over 140 installations have been made.

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This process is a flexible and economical method of reforming natural gas and L.P. gas to meet the base load and peak load requirements in a natural gas situation. The process has the flexibility to produce gases of the characteristics required for interchanging with existing gas mixtures.

The operating requirements for the process are simple, and this, together with its efficiency in using raw materials, contributes to the low production costs.

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*Patent Pending

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A completely stable cyclic sulfide. Many leading companies use it at the rate of ½ pound per MMCF of gas.

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Has essentially the same characteristics as Calodorant "C", but is compounded so as to give effective odorization at 1 pound per MMCF of gas.

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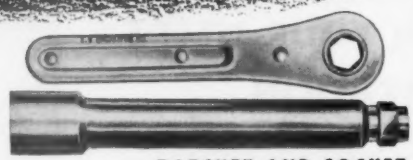

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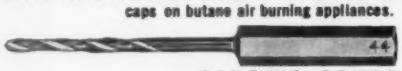

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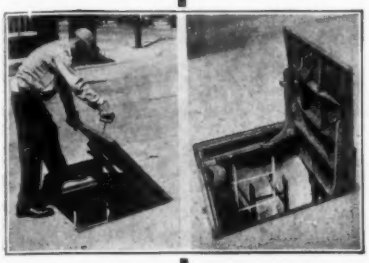

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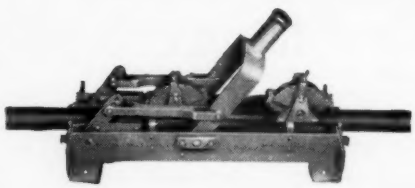

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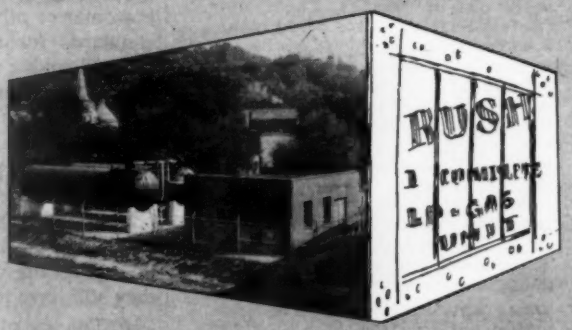

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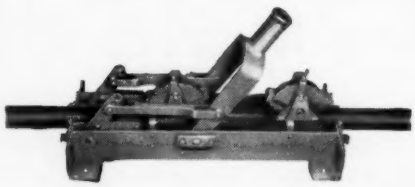

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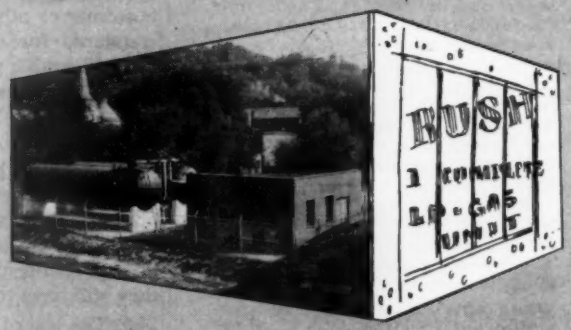

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Today and tomorrow the most important heating system you can handle!

Important—YES! With every new, years-ahead feature . . . guaranteeing dealers as never before "extra" equipment flexibility for hundreds of heating needs.

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Exclusive, revolutionary "Safety-Sealed" construction seals all combustion air and products from contact with heated room air. Expels all combustion products *outside*—through the wall.

Operation is silent, dependable—with either natural, manufactured or LP gas. Individual requirements are suited *exactly* from manual or thermostatic controls.

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GAS HOME HEATING

Approved by American Gas Association

Experience and Practices in Gas Odorizing in the Niagara Mohawk System

(Continued from page 6)

quirement. Upon request, the company shall report the kind and method of odorization."

Our company is currently recording the following daily data for each odorizing station: gallons innage, gallons used, check of machine operations, smell test intensity in distribution system, pounds of odorant per MMcf for the day and month to date, identity of operators making the inspections and kind of odorant used.

The so-called "fly-wheel" effect of the gas system itself in the odorizing operation has been questioned. The internal surfaces and deposits in gas systems most certainly do become impregnated with these odorants. That is proven every time a line having carried odorized gas is taken up or even opened. The need for hourly records of odorant rate can be questioned for this reason, but daily checks are not believed to be too often, particularly for situations supplying large numbers of customers and then, principally, to insure that the mechanism is operating properly.

Odorizing results and effects

1. It appears to us to be reasonably simple to obtain and maintain proper odor intensity to give early indication to customers of the presence of unburned gas in their homes.

2. It is less effective in disclosing street leaks where the gas has to pass through soil or water. The intensity is greatly reduced by passing through even three or four feet of damp earth.

3. The amount of sulphur added by these odorant materials has never resulted in any complaint, based on the amount of sulphur, from an industrial customer or other user. New York State standards for manufactured gas place total allowable sulphur in manufactured gas at 30 grains per 100 cf. Our supply contract for natural gas allows a maximum of 20 grains per 100 cf.

4. Excessive leak complaints from gas users can be promptly generated by over-odorizing. Even though most of these turn out to be "nuisance leaks" or the ordinary results of slow burner ignition, they still have to be answered.

5. The use of alcohol on gas odorized with sulphides reduces odor intensity. This has been correlated with dates of anti-freeze injection by our natural gas supplier. Tests show high concentration of by-product methanol has a definite masking effect.

6. We have no record of any employee or others being injured or having impaired health from handling the materials. Men use rubber gloves and wash with a solution of potassium permanganate.

7. We have no evidence that it has damaged or deteriorated our system in any way. The tankage and piping at odorizers were not attacked in five years.

8. Where natural gas is replacing manufactured gas, a high rate of odorizing is necessary initially to get such materials as oxides, tars and oils inside the old system saturated to a point where they will permit the proper intensity of odorant through to customers. This period is probably measured in days, not hours.

9. Effect of fogging oil has not yet been demonstrated to us. We fog in all districts, except in a small new system just placed in operation. Later, it may be possible to state that it takes less odorant if fogging oil is not used.

Anticipated improvements

We expect to accomplish these further improvements in our practices:

1. Use of diluter or similar instrument as an accessory in making smell tests.

2. Installation of metering devices on the liquid feeding from odorizers. Improved accuracy in determining daily the amount of liquid odorant used at the smaller stations.

General comments

Odorizing stations near communities pose a problem in avoiding nuisances or alarming reports, due to spillage, leaks, or just ordinary handling of this offensive material. We have had several neighborhood alarms from this cause. Ordinary purification oxide is effective in sponging up the mercaptans. We use sodium hypochlorite or chlorox for the same purpose on sulphides.

Drums were formerly returnable; now they are not. The disposal of non-returnable drums may become a problem. They cannot be disposed through the usual scrap channels, without preparation. One pint of fifteen per cent sodium hypochlorite is added to a full 55 gallon drum while filling with water, after which heads are knocked out and drum is junked. They may be burned out, with somewhat more difficulty.

Costs

Installed cost at a city gate station, based on 1,000 gallon storage, two odorizers housed in masonry building, with an odorizer station capacity of 200 MMcf per day, was:

Structure	*Equipment*	*Total*
$2,100	$6,300	$8,400

Operating costs during 1951 were $0.0012 per Mcf.

Properties of Natural Gas Odorants

(Continued from page 8)

room and the weight of soil can be found for each soil using the second equation, above. Using this relationship, curves were plotted, along which the natural gas in a room would be at its lower explosive limit at the same time that the first odor could be detected, as shown in figure 5.

It will be noted that the probability of attaining an explosive mixture, before detection by odor, increases when gas passes through sand, caliche, weathered limestone, cinders, and black soil respectively. It should be pointed out that the above is for an air-tight room and that under normal conditions of varying number of air changes per hour the explosion tendency would decrease.

Conclusion

From tests conducted, it appears that, with the exception of cinders, when odorized natural gas passes through the various soils tested, adsorption is the primary method by which the odorant is removed. The primary ability for a soil to remove an odorant increases with its surface area or colloid content, although water content, temperature, and oxidizing materials are other variables, the latter more so in the case of cinders.

References

1. Dotterweich, Frank H., "Natural Gas Odorants," *Gas Age*, June 8, 1950, page 23.
2. Turcotte, Patrick Andrew, "A Laboratory Study of the Adsorption of Commercial Odorants in Natural Gas While Passing Through Various Soils," A Thesis in partial fullfillment for a Master Degree, Texas College of Arts and Industries, to be published.
3. Dotterweich, Frank H., with Huff, Wilbert J., "The Development of a Standard Test for Gauging the Adsorption Power of Colloidal Ferric Oxide by Dye Adsorption," *Industrial and Engineering Chemistry*, Analytical Edition, May 15, 1940, page 277.
4. Cable, Charles Ransom, "A Pilot Plant Study of Gas Odorant Adsorption by Various Soils," A Thesis in partial fullfillment for a Master Degree, Texas College of Arts and Industries, to be published.
5. Powell, J. S., "Selection of an Odorant for Natural Gas Odorization," Technical Section, Pacific Coast Gas Association, March 8, 1950.

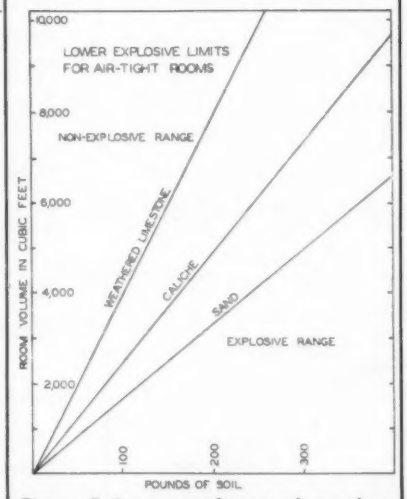

Figure 5. Room conditions when odorized natural gas passes through soils

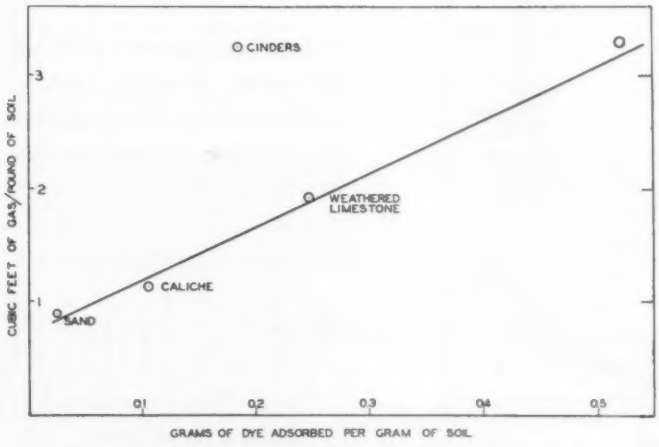

Figure 4. Dye adsorbed per gram of soil vs. cubic feet of gas per pound of soil

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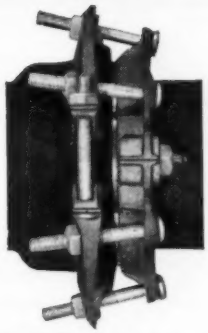

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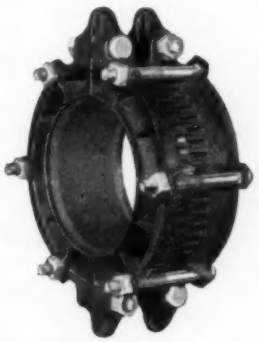

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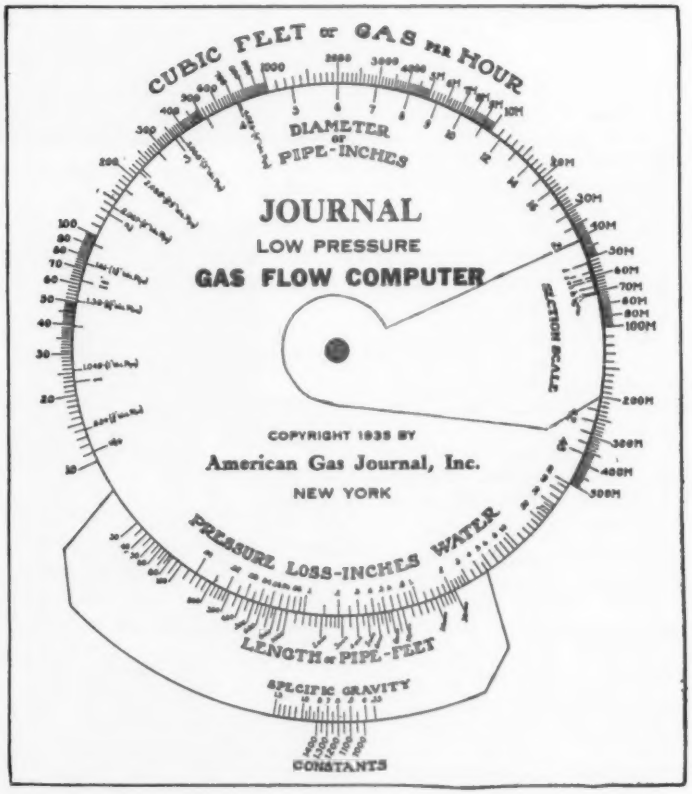

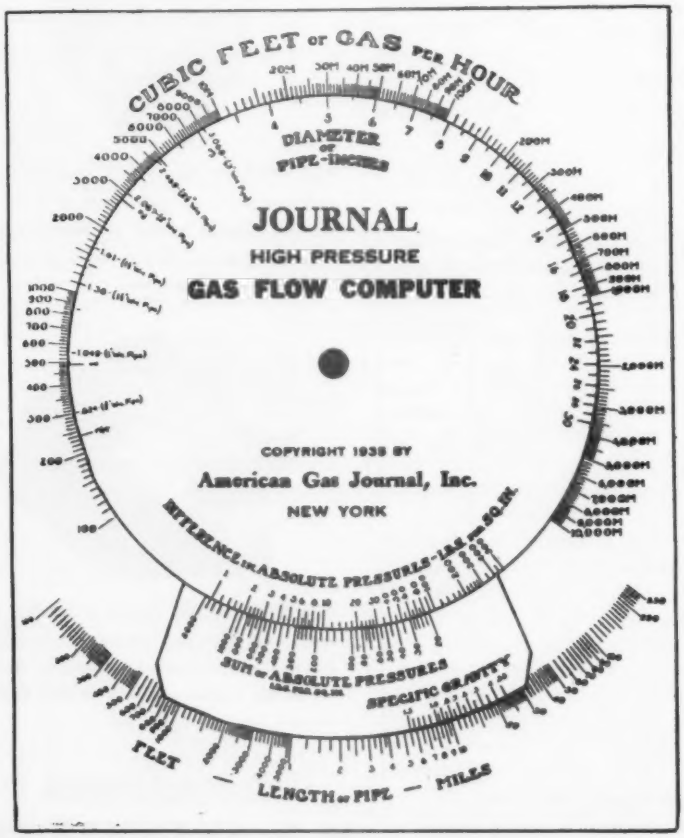

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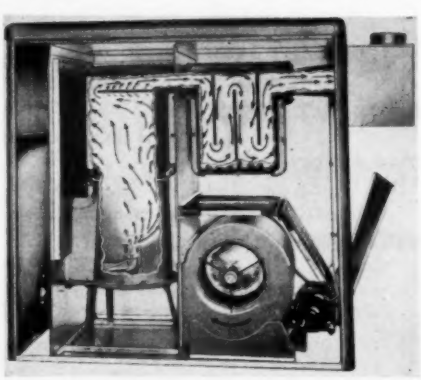

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NATURAL GAS
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Geology and the Gas Industry

GEOLOGY is the science which treats of the earth, the rocks of which it is composed, and the changes which it has undergone or is undergoing. As a science geology seeks to interpret current observations through theories or hypotheses regarding the origin of seas. The sediment thus deposited did not remain forever in the bottom of the seas. Further internal upheavals originating deep in the earth raised the sea bottom into dry land again, which in turn became subject to further erosion into another sea or lake area. Also the sediments from

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Methods of Drilling for Gas or Oil

IN the earlier days of the natural gas industry it was up to the natural gas companies to go out and find their own gas if they were to continue in business. That was before the days of the long distance pipe lines, and natural gas was served only to the communities and industries located very near to the gas producing fields. [illegible] spectacular career first as an [illegible] search for oil.

panies that own leases, drill wells and carry on their own field production operations.

Regardless of who puts down the well, or who owns the gas that eventually flows from it, the business of drilling and production is carried on in the same manner by both gas and oil operators.

As we have seen in the chapter on Geology (January 1951, A.G.J.), that science has developed to the place where the prospect of either oil or gas can be predicted [illegible] probability. But oil and gas may [illegible] another oil or

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MANUFACTURED GAS
2. REFORMED GAS

Processes for Reforming Natural Gas

THE term reforming, as used by the gas industry, means the chemical decomposition of a hydrocarbon gas such as natural gas by the use of heat to produce a larger volume of a lower heating value gas.

This type of decomposition or cracking action, technically termed pyrolysis, can be performed in a standard water gas set or in apparatus especially designed for the purpose. The usual objective [illegible]

gas company is enabled to raise its calorific [illegible] 600), 700), 800) Btu or any desired calorific val[illegible] both without increase the capacity of its distribution system is directly [illegible] of the gas

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GAS STORAGE

Methods of Storing Gas

ANY description of the methods of storing gas, to be understandable, must be prefaced by a brief discussion of some of the particular considerations in gas distribution that make storage necessary. One thing that gas has in common with electricity, and wherein it differs from other common fuels, coal or oil, is that it cannot be stored on the consumer's premises. This means that it becomes the responsibility of the utility to see to it that the gas is available for delivery to the customer at any time, and in the amounts that he requires.

A manufactured gas plant or a natural gas pipe line could conceivably be built with big enough capacity so that no matter what the peak demand was, it could instantly be met. But this would be an extremely uneconomical way of doing it, since all of the investment in excess capacity would be wasted during the off-peak periods when only the nominal demand, or base load, as it is called, was required.

The gas storage problems of the industry [illegible]

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TRANSMISSION
PIPE LINES

Transmission of Natural Gas

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MANUFACTURED GAS
COKE OVEN GAS; PRODUCER GAS
BLUE GAS; CARBURETED WATER GAS

Processes for Manufacturing Gas

MANUFACTURED gas, as the name implies, is produced from raw materials in facilities designated for that purpose. There are, strictly speaking, [illegible] manufactured gases called water gas and producer gas are [illegible] cussion will [illegible] of heat. Oil gases are made by cracking gas oil, propane, gasoline, or other hydrocarbons.

Blue gas (often called water gas) and producer gas are [illegible] these, only [illegible] and signific[illegible] of the second type of gas-making pro[illegible]

While in [illegible] to transpose [illegible] to the com[illegible]tah's is ma[illegible] distributive [illegible]

The com[illegible]ced exec[illegible]

1. The [illegible] sure, [illegible]pally [illegible]

The [illegible] in [illegible] of [illegible] in [illegible]

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DISTRIBUTION
METERING

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DISTRIBUTION
PRESSURE REGULATI[illegible]

Measurement by [illegible] Displacement

THERE are two basic methods used in the measurement of gas. First, through the positive displacement meter; and, second, through the inferential type such as the orifice meter. In a gas distribution system practically all gas is measured with a displacement meter, so, in this chapter only the positive displacement meter will be discussed.

With the gas meter, such as is used in domestic measurement and with which many people are familiar, external power cannot be furnished to operate the mechanism. It is necessary, therefore, to use the potential energy which the gas itself possesses, by means of pressure to supply the motivating power. With few exceptions, the meter arrangement of gas by the displacement principle uses the available energy in the gas itself to operate the ordinary meter. The basic principle is measured with three things. First, provide a means to accomplish three things. First, provide a means to accomplish the volume displacement members to operate the volume displacement members to operate the displacement per revolution. Second, control the displacement per revolution. Third, afford some means for counting and expressing this result as cubic feet as possible. third, afford some means for counting and expressing this result as cubic feet as possible.

Illustrations and descriptions of the meter arrangement of gas by the displacement principle uses leather diaphragms and slide valves. With few exceptions, the meter arrangement of gas by the displacement principle uses leather diaphragms and slide valves. In this the pressure of the gas is utilized to operate the meter by means of the diaphragm movement by means of the diaphragm movement, which will be discussed later. the conventional two diaphragm and two sets of valves to control the flow of gas. In the illustration, four diaphragm and valve positions of the meter are shown.

Operation of Diaphragm and Valves

In illustration "A," of Fig. 1, the left, or case, compartment of the left diaphragm is connected through to the valve to the outlet. The right, or diaphragm, compartment of this same diaphragm is connected to the inlet. The right hand diaphragm is at its extreme inward stroke, and the valve port openings to either side of this diaphragm are closed by the valve. When a valve to an appliance on the outlet side of the meter is opened, the pressure in the line will start to decrease and will reduce the pressure in the meter chamber, which is connected to this line. The pressure on the opposite side of the diaphragm will remain at the initial pressure; therefore, due to the unbalance in pressure or pressure differential, the left case will move to the left. The gas in the left case will move through the exhaust port of the valve. This flow will continue to

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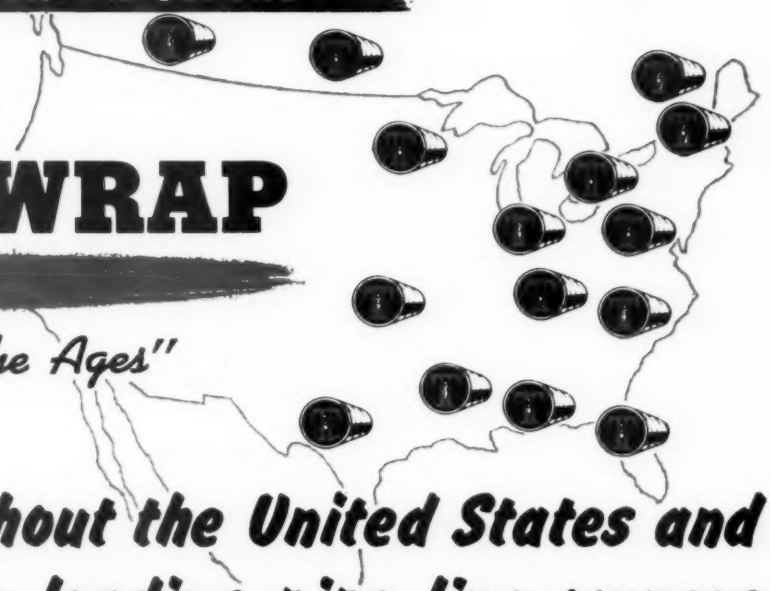

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